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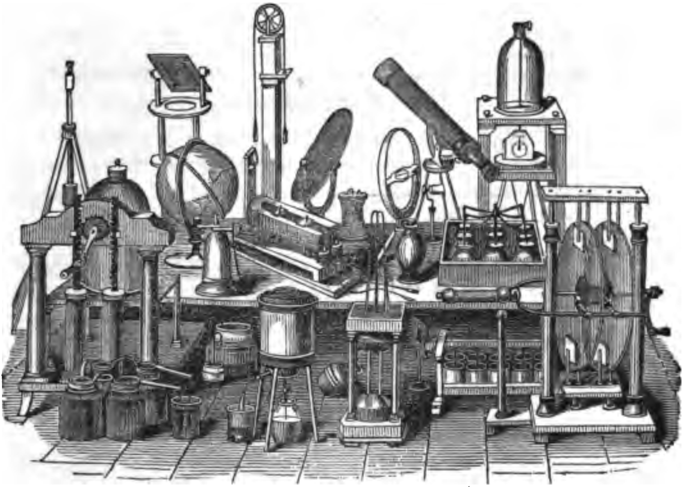

ILLUSTRATED BY THREE HUNDRED AND TWENTY-FOUR ENGRAVINGS.

BY J. L. COMSTOCK, M. D.,
AUTHOR OF INTRODUCTION TO MINERALOGY, ELEMENTS OF CHEMISTRY, INTRODUCTION TO BOTANY,
OUTLINES OF GEOLOGY, OUTLINES OF PHYSIOLOGY, NATURAL HISTORY OF BIRDS, ETC.

TWO HUNDRED AND FIFTH EDITION,
REVISED AND ENLARGED.

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PREFACE

TO THE SIXTH STEREOTYPE REVISION.

THE author has the satisfaction of being again called upon by the publishers for another revision of his Natural Philosophy, this being the sixth time it has been stereotyped.

In this revision, in order to make room for new matter, some parts of the old, have been omitted, while others have been abridged, so that the book has not been enlarged, nor is the matter so changed as to make it unfit for use in classes with the former edition.

As before, the author has availed himself of the additions and improvements made by Professor Lees of "the Naval and Military Academy of Edinburgh," and of those of Professor Hoblyn, Lecturer in "The Institute of Medicines and Arts," London, these gentlemen having each done him the honor to associate their names with his, in two several editions of this work.

The new matter incorporated in this edition, embraces a great variety of subjects, it having been the object of the author, to include all the most important discoveries and improvements in the arts, coming within the scope of his book, which have been made since the last edition.

Besides those of lesser note, the following are thought of sufficient importance to attract the attention of the teacher and student, who are desirous of keeping up with the improvements of the times in the acquirement of philosophical knowledge. The subjects and illustrations of this list have not been embraced in any former edition of this work.

Dick's Anti-Friction Press; The First Vacuum; Centrifugal Pump; Balloon and Parachute; Pump and Fire Engine; Spheroidal Theory of Steam Boiler Explosions; Distillation; Twilight; Compound Microscope; Hydro-Electricity; Gasometer and Meter; Rotation of the Earth.

The following subjects, here added, are illustrated with new drawings—Attraction of Gravity; Elasticity; Action and Re-action; Center of Gravity; Inclined Plane; Hydrostatic Press; Barker's Mill; The Condenser; Barometer; Fire Engine; Expansion and Circulation by Heat; Thermometer; Force of Steam; Reflection by Mirrors; Acoustics; Counter Currents of Air; Vision; Astronomy; Electricity; Magnetism. More than seventy new cuts have been added, and the whole work, the author hopes, has been made more acceptable to the public than heretofore.

And finally, perhaps, the author may add, that such has been the indulgence of the public, that more than seven hundred thousand copies of this book have been sold in this country, besides those published in England, Scotland, and Prussia.

J. L. C.

HARTFORD, CT., March, 1856.

NOTICE BY THE PUBLISHERS.

THE publishers of Dr. Comstock's Natural Philosophy will not withhold from the public an expression of the gratification they feel as Americans, at the manner in which the work has been received and appreciated in Europe.

It has been twice edited and republished in the Queen's dominions. First in Scotland, the editor being Prof. Lees, "of the Naval and Military Academy, and Lecturer on Natural Philosophy, Edinburgh."

In his Preface the editor says: "Among the many works on Natural Philosophy which have made their appearance of late years, we certainly have not met with one uniting in a greater degree the two grand requisites of precision and simplicity, than the work of Dr. Comstock. * * * * The principles of the science are stated with singular clearness, and illustrated by the most apt, and interesting examples. * * * * The development of the various branches is effected by the help of well-designed diagrams, and these by no means sparingly introduced. *Published by Scott, Webster & Geary, London.*

During the last year the Philosophy was again edited by Prof. Hoblyn of Oxford, now "Lecturer in the Institute of Medicine and Arts," *London;* and author of a Medical Dictionary republished in this country. This edition is dedicated to Marshall Hall, M. D., F. R. S., one of the chiefs of the Medical profession in the metropolis, and who, it appears, has introduced it to his pupils in the lecture room.

The following is an extract from Prof. Hoblyn's Preface to his edition:—

"This Manual of Natural Philosophy claims no higher merit than that of being a republication of the popular treatise of Dr. Comstock, of Hartford, in the United States, enlarged and to a certain extent remodeled. His colleague feels a peculiar pleasure in the association of his own name with that of an author, who has earned a well-merited reputation in the pursuit of physical science. As an elementary work, requiring for its perusal no mathematical attainment, nor indeed any previous knowledge of Natural Philosophy, it is at once simple, intelligible, and in most parts familiar." *Published by Adam Scott, Charter House Square, London.*

Besides these two editions of the entire work, Dr. Comstock's Philosophy has been published in parts, in the form of scientific tracts, at a shilling each, for general circulation in England. We understand also, that the work has been translated into German, for the use of the public schools in Prussia.

Having thus undergone the critical examination of two Professors of high attainments abroad, who have each corrected its errors, and added to its pages, and of whose labors, we have no doubt, the author has availed himself, we now offer this revised edition to the public, with renewed confidence in its correctness, as well as its adaptation to the purpose for which the work is intended.

NEW YORK.

NATURAL PHILOSOPHY, &c.

CHAPTER I.

THE PROPERTIES OF BODIES.

NATURAL PHILOSOPHY, or the *Science of Nature*, has for its objects the investigation of the properties of all natural bodies and their mutual action on each other. The term *Physics* has a similar meaning.

1. A BODY *is any substance of which we can gain a knowledge by our senses. Hence, air, water, and earth, in all their modifications, are called bodies.*

2. There are certain properties which are common to all bodies. These are called the essential properties of bodies. They are *Impenetrability*, *Extension*, *Figure*, *Divisibility*, *Inertia*, and *Attraction*.

3. IMPENETRABILITY.—By impenetrability, is meant that two bodies can not occupy the same space at the same time, or, that the ultimate particles of matter can not be penetrated. Thus, if a vessel be exactly filled with water, and a stone or any other substance heavier than water, be dropped into it, a quantity of water will overflow, just equal to the size of the heavy body. This shows that the stone only separates or displaces the particles of water, and therefore that the two substances can not exist in the same place at the same time. If a glass tube open at the bottom, and closed with the thumb at the top, be pressed down into a vessel of water, the liquid will not rise up and fill the tube, because the air already in the tube resists it; but if the thumb be removed, so that the air can pass out, the water will instantly rise as high on the inside of the tube as it is on

---

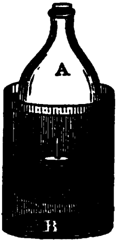
What are the objects of natural philosophy? 1. What is a body? 2. Mention several bodies. What are the essential properties of bodies? 3. What is meant by *impenetrability?* How is it proved that air and water are inpenetrable?

the outside. This shows that the air is impenetrable to the water.

4. If a nail be driven into a board, in common language, it is said to penetrate the wood, but in the language of philosophy, it only *separates* or *displaces* the particles of the wood. The same is the case, if the nail be driven into a piece of lead; the particles of the lead are separated from each other, and crowded together, to make room for the harder body, but the particles themselves are by no means penetrated by the nail.

5. *Glass Receiver.*—Again, if a glass receiver, A, *Fig.* 1, be inverted over a lighted taper, floating on a cork in the vessel of water B, the receiver may be pushed to the bottom of the containing vessel, the taper continuing to burn, as long as the confined air contains oxygen, the impenetrability of that elastic fluid, preventing the water from rising in the inner vessel, so as to extinguish the light, a convincing proof that no two bodies can occupy the same place at the same time.

FIG. 1.



Glass Receiver.

6. Extension.—*Every body, however small, must have length. breadth, and thickness, since no substance can exist without them. By extension, therefore, is only meant these qualities. Extension has no respect to the size or shape of a body.*

7. The size and shape of a block of wood a foot square is quite different from that of a walking-stick. But they both equally possess length, breadth, and thickness, since the stick might be cut into little blocks, exactly resembling in shape the large one. And these little cubes might again be divided until they were only the hundredth part of an inch in diameter, and still it is obvious that they would possess length, breadth, and thickness, for they could yet be seen, felt, and measured.

8. Figure or form *is the result of extension, for we can not conceive that a body has length and breadth, without its also having some kind of figure, however irregular.*

9. Some solid bodies have certain or determinate forms which are produced by nature, and are always the same, wherever they are found. Thus, a crystal of quartz, *Fig.* 2, has six sides, while a garnet, *Fig.* 3, has twelve sides,

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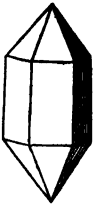
4. When a nail is driven into a board or piece of lead, are the particles of these bodies penetrated or separated? 5. Explain Fig. 1. 6. What is meant by extension? 7. In how many directions do bodies possess extension? 8. Of what is figure or form the result? Do all bodies possess figure? 9. What solids are regular in their forms?

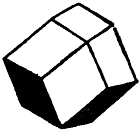
these numbers being invariable. Some solids are so irregular, that they can not be compared with any mathematical figure. This is the case with the fragments of a broken rock, chips of wood, fractured glass, &c.; these are called *amorphous* shapes.

FIG. 2.



Quartz.

FIG. 3.



Garnet.

10. Fluid bodies have no determinate forms, but take their shapes from the vessels in which they happen to be placed.

11. DIVISIBILITY.—*By the divisibility of matter, we mean that a body may be divided into parts, and that these parts may again be divided into other parts, and so on without limit.*

12. It is quite obvious, that if we break a piece of marble into two parts, these two parts may again be divided, and that the process of division may be continued until these parts are so small as not individually to be seen or felt. But as every body, however small, must possess extension and form, so we can conceive of none so minute but that it may again be divided. There is, however, possibly a limit, beyond which bodies can not actually be divided, for there may be reason to believe that the atoms of matter are indivisible by any means in our power. But under what circumstances this takes place, or whether it is in the power of man during his whole life, to pulverize any substance so finely, that it may not again be broken, is unknown.

We can conceive, in some degree, how minute must be the particles of matter, from circumstances that every day come within our knowledge.

13. A single grain of musk will scent a room for years, and still lose no appreciable part of its weight. Here, the particles of musk must be floating in the air of every part of the room, otherwise they could not be every where perceived.

14. Gold is hammered so thin, as to take 282,000 leaves to make an inch in thickness. Here, the particles still adhere to each other, notwithstanding the great surface which they

---

10. What bodies are irregular? 11. What is meant by divisibility of matter? Is there any limit to the divisibility of matter? 12. Are the atoms of matter divisible? 13. What examples are given of the divisibility of matter? 14. How many leaves of gold does it take to make an inch in thickness? How many square inches may a grain of gold be made to cover?

cover,—a single grain being sufficient to extend over a surface of fifty square inches.

15. INDESTRUCTIBILITY.—*This term means that nothing is destroyed.* The ultimate particles of matter, however widely they may be diffused, are not individually destroyed, or lost, but under certain circumstances, may again be collected into a body without change of form. Mercury, water, and many other substances, may be converted into vapor, or distilled in close vessels, without any of their particles being lost. In such cases, there is no decomposition of the substances, but only a change of form by the heat, and hence the mercury and water assume their original state again on cooling.

16. Where bodies suffer decomposition or decay, their elementary particles, in like manner, are neither destroyed nor lost, but only enter into new arrangements or combinations with other bodies.

17. When a piece of wood is heated in a close vessel, such as a retort, we obtain water, an acid, several kinds of gas, and there remains a black, porous substance, called *charcoal.* The wood is thus decomposed, or destroyed, and its particles take a new arrangement, and assume new forms, but that nothing is lost, is proved by the fact that if the water, acid, gases, and charcoal, be collected and weighed, they will be found exactly as heavy as the wood was before distillation.

18. Bones, flesh, or any other animal substance, may in the same manner be made to assume new forms, without losing a particle of the matter which they originally contained.

19. The decay of animal or vegetable bodies in the open air, or in the ground, is only a process by which the particles of which they were composed, change their places and assume new forms.

20. The decay and decomposition of animals and vegetables on the surface of the earth form the soil, which nourishes the growth of vegetables; and these, in their turn, form the nutriment of animals. Thus is there a perpetual change from life to death, and from death to life, and as constant a succession in the forms and places, which the particles of matter assume. Nothing is lost, and not a particle of matter is struck out of existence. The same matter of which every living animal, and every vegetable was formed since the creation, is still

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15. Under what circumstances may the particles of matter again be collected in their original form? 16. What is meant by indestructibility? 17 When bodies suffer decay, are their particles lost? 18. What becomes of the particles of bodies which decay? 19 Is it probable that any matter has been annihilated or added, since the first creation? 20 What is said of the particles of matter of which we are made?

in existence. As nothing is lost or annihilated, so it is probable that nothing has been added, and that we, ourselves, are composed of particles of matter as old as the creation.

21. INERTIA.—*Inertia means passiveness, or want of power, or inactivity of matter. Thus matter is, of itself, equally incapable of putting itself in motion, or of bringing itself to rest when in motion.*

22. It is plain that a rock on the surface of the earth never changes its position in respect to other things on the earth. It has of itself no power to move, and would, therefore, forever lie still, unless moved by some external force. This fact is proved by the experience of every person, for we see the same objects lying in the same positions all our lives. Now, it is just as true, that inert matter has no power to bring itself to rest, when once put in motion, as it is that it can not put itself in motion when at rest, for having no life, it is perfectly passive, both to motion and rest; and therefore either state depends entirely upon circumstances.

23. Common experience proving that matter does not put itself in motion, we might be led to believe, that rest is the natural state of all inert bodies; but a few considerations will show that motion is as much the natural state of matter as rest, and that either state depends on the resistance, or impulse, of external causes.

24. If the air be exhausted, or pumped out of a vessel by means of an air-pump, and a common top, with a small, hard point, be set in motion in it, the top will continue to spin for hours, because the air does not resist its motion. A pendulum set in motion, in an exhausted vessel, will continue to swing without the help of clock work, for a whole day, because there is nothing to resist its perpetual motion but the small friction at the point where it is suspended, and gravity.

25. We see then, that it is the resistance of the air, of friction, and of gravity, which cause bodies once in motion to cease moving, or come to rest, and that dead matter, of itself, is equally incapable of causing its own motion, or its own rest.

26. We have perpetual examples of the truth of this doctrine, in the moon, and other planets. These vast bodies move through spaces which are void of the obstacles of air and friction, and their motions are the same that they were thousands of years ago, or at the beginning of creation. Thus it is proved

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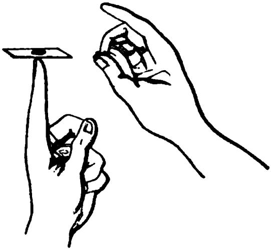
21. What does inertia mean? 22. Is rest or motion the natural state of matter? 23. Why will a top spin, or a pendulum swing, longer in an exhausted vessel than in the air? 25. What are the causes which resist the perpetual motion of bodies?

that bodies once in motion, do not cease to move without an efficient cause. On the contrary, the want of motion, or the inertia of bodies, as shown by the force required to put them in motion is proved by obvious and daily facts. Thus when one is standing in a boat, and another suddenly pushes her from the shore, the feet are moved with the boat, while the body being at rest, or in a state of inertia, falls toward the shore, because it resists the sudden motion which the feet has acquired.

27. But on the other hand, when the boat and standing man have acquired motion, and the boat suddenly stops, the man is pitched forward because his inertia prevents his coming instantly to rest.

28. A pretty little experiment illustrating this subject is represented by Fig. 4. If a small card be placed on the end of the finger, and on the card, a penny, the card may be thrown away by the snap of the finger, leaving the coin in its place, because the inertia of the penny refuses to partake of the instant motion of the card.

FIG. 4.



Card and Penny.

29. Attraction.—*By attraction is meant that property or quality in the particles of bodies, which makes them tend toward each other.*

30. We know that substances are composed of small atoms, or particles of matter, and that it is a collection of these, united together, that form all the objects with which we are acquainted. Now, when we come to divide, or separate any substance into parts, we do not find that its particles have been united or kept together by glue, little nails, or any such mechanical means, but that they cling together by some power, not obvious to our senses. This power we call *Attraction*, but of its nature or cause, we are entirely ignorant. Experiment and observation, however, demonstrate that this power pervades

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26. Where have we an example of continued motion without the existence of air and friction? 27. When the boat is pushed suddenly from the shore, why does the standing man fall? Why is the man pitched forward when the boat suddenly stops? 29. What is meant by attraction? 30. What is known about the cause of attraction? Is attraction common to all kinds of matter, or not? What effect does this power have upon the planets?

all material things, and that under different modifications, it not only makes the particles of bodies adhere to each other, but is the cause which keeps the planets in their orbits as they pass through the heavens.

31. Attraction has received different names, according to the circumstances under which it acts.

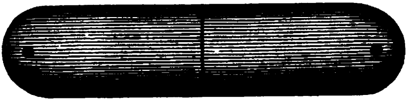
32. The force which keeps the particles of matter together, to form bodies, or masses, is called *Attraction of cohesion.* That which inclines different masses toward each other is called *Attraction of gravitation.* That which causes liquids to rise in tubes, is called *Capillary attraction.* That which forces the particles of substances of different kinds to unite, is known under the name of *Chemical attraction.* That which causes the needle to point constantly toward the poles of the earth, is *Magnetic attraction;* and that which is excited by friction in certain substances, is known by the name of *Electrical attraction.*

33. The following illustrations, it is hoped, will make each kind of attraction distinct and obvious to the mind of the student.

34. ATTRACTION OF COHESION *acts only at insensible distances, as when the particles of bodies apparently touch each other.*

35. Take two pieces of lead, *Fig.* 5, of a round form, an inch in diameter and two inches long; flatten one end of each and make through it an eye-hole for a string. Make the other ends of each as smooth as possible, by cutting them with a sharp knife. If now the smooth surfaces be brought together, with a slight turning pressure, they will adhere with such force that two men can hardly pull them apart by the two strings.

FIG. 5.



Cohesion.

36. In like manner, two pieces of plate glass, when their surfaces are cleaned from dust, and they are pressed together, will adhere with considerable force. Other smooth substances present the same phenomena.

37. This kind of attraction is much stronger in some bodies than in others. Thus, it is stronger in the metals than in most

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31. Why has attraction received different names? 32. How many kinds of attraction are there? How does the attraction of cohesion operate? What is meant by attraction of gravitation? What by capillary attraction? 33. What by chemical attraction? What is that which makes the needle point toward the pole? How is electrical attraction excited? 34. Give an example of cohesive attraction? 36. In what substances is cohesive attraction the strongest? In what substances is it the weakest?

other substances, and in some of the metals it is stronger than in others. In general it is most powerful among the particles of solid bodies, weaker among those of liquids, and probably entirely wanting among elastic fluids, such as air and the gases.

38. *When the particles of fluids are left to arrange themselves according to the laws of attraction, the bodies which they compose assume the form of a globe or ball.*

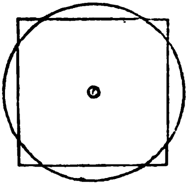
39. The manufacture of shot is a striking illustration of this law. The lead is melted and poured into a sieve, at the height of about two hundred feet from the ground. The stream of lead, immediately after leaving the sieve, separates into round globules, which, before they reach the ground, are cooled and become solid, and thus are formed the shot used by sportsmen.

40. To account for the globular form in all cases, we have only to consider that the particles of matter are mutually attracted toward a common center, and in liquids being free to move, they arrange themselves accordingly.

41. In all figures except the globe or ball, some of the particles must be nearer the center than others. But in a body that is perfectly round, every part of the outside is exactly at the same distance from the center.

42. Thus, the corners of a cube, or square, are at much greater distances from the center than the sides, while the circumference of a circle or ball is every where at the same distance from it. This difference is shown by *Fig.* 6, and it is quite obvious, that if the particles of matter are equally attracted toward the common center, and are free to arrange themselves, no other figure could possibly be formed, since then every part of the outside is equally attracted.

FIG. 6.



Globular form.

43. The sun, earth, moon, and indeed all the heavenly bodies, are illustrations of this law, and therefore were probably in so soft a state when first formed, as to allow their particles freely to arrange themselves accordingly.

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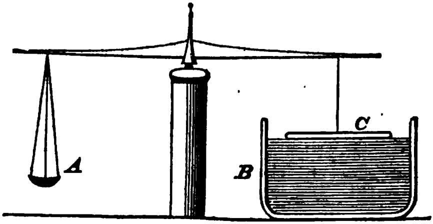
38. What form do fluids take, when their particles are left to their own arrangement ? 39. Give examples of this law. 40. How is the globular form which liquids assume accounted for ? If the particles of a body are free to move, and are equally attracted toward the center, what must be its figure ? 41. Why must the figure be a globe ? 42. What great natural bodies are examples of this law ?

44. ADHESION.—The attraction between solids and liquids is termed *adhesion*. This is well illustrated by means of *Fig.* 7.

FIG. 7.

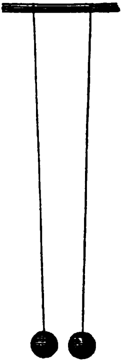


Adhesion between solids and liquids.

First, very nicely balance the plate of copper, C, by means of weights in the cup, A, and then slide the vessel of water, B, under the copper, pouring in more of the fluid until the metal just touches it. Now on placing weights in A, it will be found that the metal adheres to the water with so much force, that if the plate has an area of about seven inches, it will require a weight of more than 1000 grains to raise it from the surface of the water.

45. ATTRACTION OF GRAVITATION.—*As the attraction of cohesion unites the particles of matter into masses or bodies, so the attraction of gravitation tends to force these masses toward each other, to form those of still greater dimensions.* The term gravitation, does not here strictly refer to the weight of bodies, but to the attraction of the masses of matter toward each other, whether downward, upward, or horizontally.

FIG. 8.



Attraction

46. The attraction of gravitation is mutual, since all bodies not only attract other bodies, but are themselves attracted.

47. Two cannon-balls, when suspended by long cords, so as to hang quite near each other, are found to exert a mutual attraction, so that neither of the cords are exactly perpendicular, but they approach each other as in *Fig.* 8.

48. In the same manner, the heavenly bodies, when they approach each other, are drawn out of the line of their paths, or orbits by mutual attraction.

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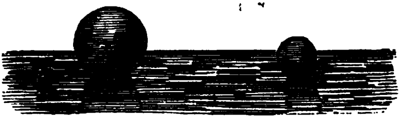
44. What explanation can you give of Fig. 7? 45. What is meant by attraction of gravitation? 46. Can one body attract another without being itself attracted? 47 How is it proved that bodies attract each other?

49. Attraction, in technical language, is inversely as the squares of the distances between the two bodies. That is, in proportion as the square of the distance increases, in the same proportion attraction decreases, and so the contrary. Thus, if at the distance of 2 feet, the attraction be equal to 4 pounds, at the distance of 4 feet, it will be only 1 pound; for the square of 2 is 4, and the square of 4 is 16, which is 4 times the square of 2. On the contrary, if the attraction at the distance of 6 feet be 3 pounds, at the distance of 2 feet it will be 9 times as much, or 27 pounds, because 36, the square of 6, is equal to 9 times 4, the square of 2.

50. The law of attraction in masses is very satisfactorily shown by the two little cork balls in *Fig.* 9. They are covered with varnish, or bees'-wax, to repel the water.

FIG. 9.



Attraction of cork balls.

Two such balls placed on the surface of a dish of water, two or three inches apart, and not near the side of the dish, will soon begin to approach each other; their velocities being in proportion to their sizes, and increasing as their distances diminish, until quite near, when they rush together as though they had life.

51. Terrestrial Gravity.—*This is so called in order to distinguish the weight or gravity on the earth, from that of the planets which may be called celestial gravity.*

52. *The force of gravitation being in proportion to the quantity of matter bodies contain, and their distances from each other, as already explained, it follows that the weight of the same body must vary in proportion to its distance from another body.*

The force of gravity, or the weight of a body is greatest at the surface of the earth, and from this point it diminishes both upward and downward.

53. It diminishes upward, because it is removed further from the center of gravity, which is the center of the earth, and downward because the attraction of the earth is thus exerted

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49. By what law or rule, does the force of attraction increase? 50. Give an example of this rule. 51. How is attraction illustrated by Fig. 9? 52. What is terrestrial gravity? 53. Where is terrestrial gravity the greatest? 54. Why does it diminish both upward and downward?

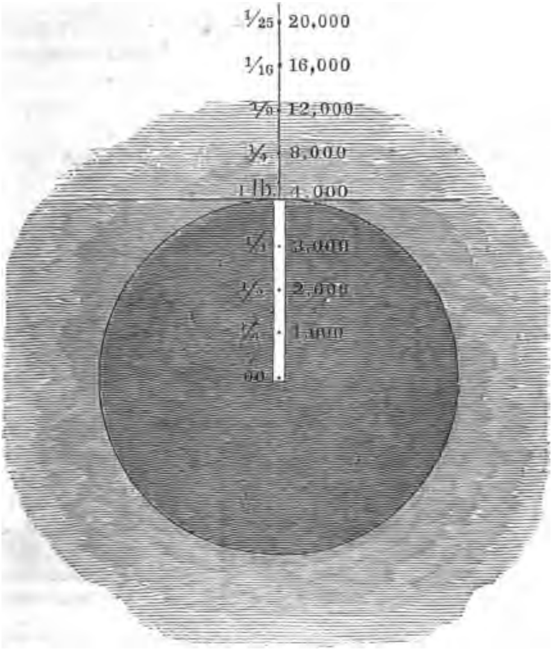
in all directions, instead of being entirely downwards as it is at the surface.

54. On this principle it is that mathematicians have estimated that a body at the surface of the earth weighing one pound would weigh nothing at the distance of 4,000 miles downward, because it would there be at the center of the earth, whence the attraction is equal on all sides. The diminution here, is simply as the distance of the center decreases.

On the contrary, the diminution upwards from the earth's surface is as the square of the distance, as we have already explained —hence the weight of a pound at the surface, would be only equal to one quarter of a pound at the height of 4,000 miles, that is 8,000 miles from the center, this being the square of 4,000.

The following diagram, Fig. 10, will illustrate this subject.

FIG. 10.



Attraction of Gravity.

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54. Explain Fig. 10, and show the reasons why the same weight increases or diminishes as it is moved up or down from the earths surface.

55. The line marked 4,000 shows the semi-diameter of the earth, which is nearly 8,000 miles in diameter. The center of the earth marked 00, indicates the absence of weight at this point, a pound weight at the surface weighing one quarter of a pound at 1,000 miles from the center, and so in this proportion, increasing upward, as already explained. The ratio of diminution, from the surface upward, has been already illustrated and explained.

56. Some bodies of the same bulk contain a much greater quantity of matter than others: thus, a piece of lead contains about twelve times as much matter as a piece of cork of the same dimensions, and therefore a piece of lead of any given size, and a piece of cork twelve times as large, will attract each other equally.

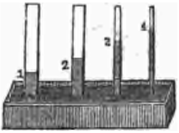
57. CAPILLARY ATTRACTION.—*The force by which small tubes, or porous substances, raise liquids above their levels, is called capillary attraction.*

58. If a small glass tube be placed in water, the water on the inside will be raised above the level of that on the outside of the tube. The cause of this seems to be nothing more than the ordinary attraction of the particles of matter for each other. The surfaces, of a small orifice are so near each other as to attract the particles of the fluid on their opposite sides, and as all attraction is strongest in the direction of the greatest quantity of matter, the water is raised upward, or in the direction of the length of the tube. On the outside of the tube, the opposite surfaces, it is obvious, can not act on the same column of water, and therefore the influence of attraction is here hardly perceptible in raising the fluid. This seems to be the reason why the fluid rises higher on the inside than on the outside of the tube.

59. *Height and size of the bore.*—The height to which the fluid will rise seems to depend, not on the specific gravity of the fluid, but on the size of the bore.

60. Thus, if the four glass tubes, shown by *Fig.* 11, are respectively the 10th, 20th, 40th, and 80th of an inch in diameter, then the height of the fluid in each will be inversely as their several diameters.

FIG. 11.



Capillary attraction.

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56. What would be the difference of attraction between a cubic inch of lead, and a cubic inch of cork? Why would there be so much difference? 57. What is meant by capillary attraction? 58. How is this kind of attraction illustrated with glass tubes? Why does the water rise higher in the tube than it does on the outside? 59. On what does the height of the fluid in capillary tubes depend? 60. Explain Fig. 11.

61. On comparing the elevation of several fluids in tubes of the same diameter, it has been found that water rose more than three times as high as sulphuric acid, though the latter is nearly twice as heavy as the former, and therefore contains a proportionate quantity of attractive matter. The cause of this difference is unknown.

62. *Prevents evaporation.*—It is very remarkable that capillary attraction prevents evaporation. Thus, fine glass tubes, open at both ends, and containing water, were exposed to the influence of the sun, in the open air, for months, without losing the least portion of their contents.

63. It is well known that mercury in a small vertical tube is depressed around the sides next to the glass; but rises in the center, forming the section of a ball. This is owing to the strong attraction the particles of this metal have for each other, while they appear to have none for the glass. This attraction is beautifully shown by the little bright globules which mercury forms on being thrown on a smooth surface.

64. A great variety of porous substances are capable of capillary attraction. If a piece of sponge or a lump of sugar be placed so that its lowest corner touches the water, the fluid will rise up and wet the whole mass. In the same manner, the wick of a lamp will carry up the oil to supply the flame, though the flame is several inches above the level of the oil.

65. On the same principle it is well known, that dry wood, or a rope, being moistened with water, are thereby increased in bulk, so that rocks are split by the swelling of wedges exposed to the rain, and ropes, as the rigging of a ship are made taught by throwing water on them, and what housewife has not had her clothes-line broken by a shower of rain?

66. Chemical Attraction *takes place between the particle of substances of different kinds, and unites them into one compound.*

67. This species of attraction takes place only between the particles of certain substances, and is not, therefore, a universal property. It is also known by the name of *chemical affinity*, because the particles of substances having an affinity between them, will unite, while those having no affinity for each other do not readily enter into union.

68. There seems, indeed, in this respect, to be very singular

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61. What is the difference in height between sulphuric acid and water? 62. What is said of its preventing evaporation? 63. Why does mercury form a section of a ball in a glass tube? 65. On what principle is it said that rocks are split and ropes broken? 66. What is the effect of chemical attraction? 67. By what other name is this kind of attraction known? 68. What effect is produced when marble and sulphuric acid are brought together? What is the effect when glass and this acid are brought together? What is the reason of this difference?

preferences, and dislikes, existing among the particles of matter. Thus, if a piece of marble be thrown into sulphuric acid, their particles will unite with great rapidity and commotion, and there will result a compound differing in all respects from the acid or the marble. But if a piece of glass, quartz, gold, or silver, be thrown into this acid, no change is produced on either, because their particles have no affinity.

69. Sulphur and quicksilver, when heated together, will form a beautiful red compound, known under the name of *vermilion*, and which has none of the qualities of sulphur or quicksilver.

70. Oil and water have no affinity for each other, but potash has an attraction for both, and therefore oil and water will unite when potash is mixed with them. In this manner, the well-known article called *soap* is formed. But the potash has a stronger attraction for an acid than it has for either the oil or the water; and therefore, when soap is mixed with an acid, the potash leaves the oil, and unites with the acid, thus destroying the old compound, and at the same instant forming a new one.

71. MAGNETIC ATTRACTION.—There is a certain ore of iron, a piece of which, being suspended by a thread, will always turn one of its sides to the north. This is called the *loadstone*, or *natural magnet*, and when it is brought near a piece of iron, or steel, a mutual attraction takes place, and under certain circumstances the two bodies will come together, and adhere to each other. This is called *Magnetic Attraction.* When a piece of steel or iron is rubbed with a magnet, the same virtue is communicated to the steel, and it will attract other pieces of steel, and if suspended by a string, one of its ends will constantly point toward the north, while the other, of course, points toward the south. This is called an *artificial* magnet. The *magnetic needle* is a piece of steel, first touched with the loadstone, and then suspended, so as to turn easily on a point. By means of this instrument, the mariner guides his ship through the pathless ocean. *See Magnetism.*

72. ELECTRICAL ATTRACTION.—When a piece of glass, or sealing-wax, is rubbed with the dry hand, or a piece of cloth, and then held toward any light substance, such as hair or thread, the light body will be attracted by it, and will adhere

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69. When sulphur and quicksilver are combined, what is formed? **70.** How may oil and water be made to unite? What is the composition thus formed called? How does an acid destroy this compound? What is the reason that hard water will not wash? **71.** What is a natural magnet? What is meant by magnetic attraction? What is an artificial magnet? What is a magnetic needle? What is its use?

for a moment to the glass or wax. The influence which thus moves the light body is called *Electrical Attraction.* When the light body has adhered to the surface of the glass for a moment, it is again thrown off, or repelled, and this is called *Electrical Repulsion. See Electricity.*

73. We have thus described and illustrated all the universal or inherent properties of bodies, and have also noticed the several kinds of attraction which are peculiar, namely, Chemical, Magnetic, and Electrical. There are still several properties to be mentioned. Some of them belong to certain kinds of matter in a peculiar degree, while other kinds possess them but slightly, or not at all. These properties are as follows:

74. Density.—*This property relates to the compactness of bodies, or the number of particles which a body contains within a given bulk. It is closeness of texture.*

75. Bodies which are most dense, are those which contain the least number of pores. Hence, the density of the metals is much greater than that of wood. Two bodies being of equal bulk, that which weighs most is most dense. Some of the metals may have this quality increased by hammering, by which their pores are filled up, and their particles are brought nearer to each other. The density of air is increased by forcing more into a close vessel than it naturally contained.

76. Rarity.—*This is the quality opposite to density, and means that the substance to which it is applied is porous and light.* Thus, air, water, and ether are rare substances, while gold, lead, and platina are dense bodies.

77. Hardness.—*This property is not in proportion, as might be expected, to the density of the substance, but to the force with which the particles of a body cohere, or keep their places.*

78. Glass, for instance, will scratch gold or platina, though these metals are much more dense than glass. It is probable, therefore, that these metals contain the greatest number of particles, but that those of the glass are more firmly fixed in their places.

79. The following table shows the comparative hardness and specific gravity of most of the gems, and some other minerals.

Substances.	Hardness.	Sp.Gr.	Substances.	Hardness.	Sp.Gr.
Diamond	20	3.7	Sapphire	17	3.8
Ruby	16	3.5	Topaz	14	3.5

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72. What is meant by electrical attraction? What is electrical repulsion. 73. What properties of bodies have been described? 74. What is density? 75. What bodies are most dense? How may this quality be increased in metals? 76. What is rarity? What are rare bodies? What are dense bodies? 77. How does hardness differ from density? 78. Why will glass scratch gold or platina? 79. What is the hardest of all known bodies?

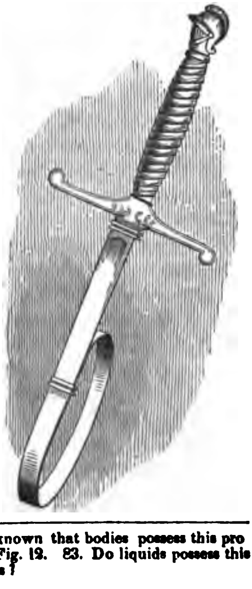
Substances.	Hardness.	Sp.Gr.	Substances.	Hardness.	Sp.Gr.
Emerald	12	2.8	Tourmaline	10	2.7
Garnet	12	2.6	Quartz	10	2.6
Cats-eye	14	2.6	Opal	9	2.6
Agate	12	2.6	Chrysolite	10	2.6
Onyx	12	2.6	Zeolite	8	2.1
Amethyst	11	2.6	Fluor-spar	7	3.5
Carnelian	11	2.7	Calcareous-spar	6	2.7
Jasper	9	2.6	Gypsum	5	2.3
Schorl	10	3.0			

It will be seen that the diamond is the hardest of all substances, being twice as hard as quartz.

80. Elasticity *is that property in bodies by which, after being forcibly compressed, or bent, they regain their original state when the force is removed.*

81. Some substances are highly elastic, while others want this property entirely. The separation of two bodies after impact, is a proof that one or both are elastic. In general, most hard and dense bodies possess this quality in greater or less degree. Ivory, glass, marble, flint, and ice, are elastic solids. An ivory ball, dropped upon a marble slab, will bound nearly to the height from which it fell, and no mark will be left on either. *Steel*, when hardened in a particular manner, and wrought into certain forms, possesses this property in the highest degree. Watch-springs, and those of carriages, as well as sword-blades, are examples. Gold, silver, copper, and platina, also have this property in a degree.

FIG. 12.



82. Some London sword blades it is said, can safely be bent until the point touches the handle. But none of these are equal to that represented by Fig. 12, called the Toledo-blade, and which was exhibited at the London Crystal Palace. This blade was bent, in presence of the public, into a perfect circle as here shown, and on being released, instantly became perfectly strait.

83. Among fluids, water, oil, and in general all such substances

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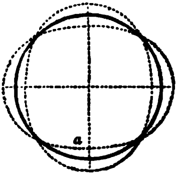
80. What is meant by elasticity? 81 How is it known that bodies possess this property? Mention several elastic solids. 82. Explain Fig. 12. 83. Do liquids possess this property? What are the most elastic of all substances?

as are denominated *liquids*, are nearly inelastic, while air, and the gaseous fluids, are the most elastic of all bodies.

84. *Change of Form.*—The change of form in an elastic body, as an India rubber ball, is shown by *Fig.* 13, where its side, on striking an impediment, is compressed to *a*, but instantly springs to *b*; the dark line between them being the surface in the natural state.

FIG. 13.



Change of Form.

85. Brittleness *is the property which renders substances easily broken, or separated into irregular fragments. This property belongs chiefly to hard bodies.*

86. It does not appear that brittleness is entirely opposed to elasticity, since, in many substances, both these properties are united. Glass is the standard, or type of brittleness; and yet a ball, or fine threads of this substance, are highly elastic, as may be seen by the bounding of the one, and the springing of the other. Brittleness often results from the treatment to which substances are submitted. Iron, steel, brass, and copper, become brittle when heated and suddenly cooled; but if cooled slowly, they are not easily broken.

87. Malleability.—*Capability of being drawn under the hammer or rolling-press.*

This property belongs to some of the metals, but not to all, and is of vast importance to the arts and conveniences of life.

88. The malleable metals are platina, gold, silver, iron, copper, lead, tin, and some others. Antimony, bismuth, and cobalt, are brittle metals. Brittleness is, therefore, the opposite of malleability.

89. Gold is the most malleable of all substances. It may be drawn under the hammer so thin that light may be seen through it. Copper and silver are also exceedingly malleable.

90. Ductility *is that property in substances which renders them susceptible of being drawn into wire.*

91. We should expect that the most malleable metals would also be the most ductile; but experiment proves that this is not the case. Thus, tin and lead may be drawn into thin leaves, but can not be drawn into small wire. Gold is the most malleable of all the metals, but platina is the most ductile.

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84. Explain Fig. 13. 85. What is brittleness? 86. Are brittleness and elasticity ever found in the same substance? Give examples. How are iron, steel, and brass made brittle? 87. What does malleability mean? 88. What metals are malleable, and what are brittle? 89. Which is the most malleable metal? 90. What is meant by ductility? 91. Are the most malleable metals the most ductile?

Dr. Wollaston drew platina into threads not much larger than a spider's web.

92. TENACITY, *in common language called toughness, refers to the force of cohesion among the particles of bodies.*

93. Tenacious bodies are not easily pulled apart. There is a remarkable difference in the tenacity of different substances. Some possess this property in a surprising degree, while others are torn asunder by the smallest force.

94. *Tenacity of Wood.*—The following is a tabular view of the absolute cohesion of the principal kinds of timber employed in the arts and in building, showing the weight which would rend a rod an inch square, and also the length of the rod, which, if suspended, would be torn asunder by its own weight.

95. It appears, by experiment, that the following is the average tenacity of the kinds of woods named; but it is found that there is much difference in the strength of the same species, and even of the different parts of the same tree.

96. The first line refers to the weight, and the other to the length, the wood being an inch square.

	Pounds.	Feet
Teak,	12,915	36,049
Oak,	11,880	32,900
Sycamore,	9,630	35,800
Beech,	12,225	38,940
Ash,	14,130	39,050
Elm,	9,540	40,500
Larch,	12,240	42,160

97. *Tenacity of the Metals.*—The metals differ much more widely in their tenacity than the woods. According to the experiments of Mr. Rennie, the cohesive power of the several metals named below, each an inch square, is equal to the number of pounds marked in the table, while the feet indicate the length required to separate each metal by its own weight.

	Pounds.	Feet.
Cast Steel,	134,256	39,455
Malleable iron,	72,064	19,740
Cast iron,	19,096	6,110
Yellow brass,	17,958	5,180
Cast copper,	19,072	5,093
Cast tin,	4,736	1,496
Cast lead,	1,824	348

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92. What is meant by tenacity? From what does this property arise? 95. Give the names of the most tenacious sorts of wood. 97. What metals are most tenacious? What metals are least tenacious?

The cohesion of fluids it is difficult to measure, though some indication of this property is derived by the different sizes of the drops of each on a plane surface.

98. RECAPITULATION.—The common or essential properties of bodies are, Impenetrability, Extension, Figure, Divisibility, Inertia, and Attraction. Attraction is of several kinds, viz., attraction of Cohesion, attraction of Gravitation, Capillary attraction, Chemical attraction, Magnetic attraction, and Electric attraction.

99. The peculiar properties of bodies are, Density, Rarity, Hardness, Elasticity, Brittleness, Malleability, Ductility, and Tenacity.

CHAPTER II.

GRAVITY.

100. THE *force by which bodies are drawn toward each other in the mass, and by which they descend toward the earth when let fall from a height, is called the force of gravity.*

101. The attraction which the earth exerts on all bodies near its surface, is called *terrestrial gravity;* and the force with which any substance is drawn downward, is called its *weight.*

102. All falling bodies tend downward, or toward the center of the earth, in a straight line from the point where they are let fall. If, then, a body descends, in any part of the world the line of its direction will be perpendicular to the earth's surface. It follows, therefore, that two falling bodies, on opposite parts of the earth, mutually fall toward each other.

103. Suppose a cannon-ball to be disengaged from a height opposite to us, on the other side of the earth, its motion in respect to us would be upward, while the downward motion from where we stand would be upward in respect to those who stand opposite to us on the other side of the earth.

104. In like manner, if the falling body be a quarter, instead of half the distance round the earth from us, its line of

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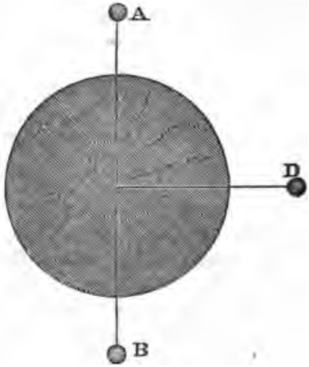
98. What are the essential properties of bodies? How many kinds of attraction are there? 99. What are the peculiar properties of bodies? 100. What is gravity? 101. What is terrestrial gravity? 102. To what point in the earth do falling bodies tend? 103. In what direction will two falling bodies, from opposite parts of the earth, tend in respect to each other? 104. In what direction will one from half-way between them meet their line?

direction will be directly across, or at right-angles with the line already supposed.

105. This will be readily understood by *Fig.* 14, where the circle is supposed to be the circumference of the earth, A, the ball falling toward its upper surface, where we stand; B, a ball falling toward the opposite side of the earth, but ascending in respect to us; and D, a ball descending at the distance of a quarter of the circle from the other two, and crossing the line of their direction at right-angles.

106. It will be obvious, therefore, that what we call *up* and *down*, are merely relative terms; and that what is down in respect to those who live on the opposite side of the earth, and so the contrary. Consequently, *down* every where means toward the center of the earth; and *up*, from the center of the earth, because all bodies descend toward the earth's center from whatever part they are let fall. This will be apparent when we consider that, as the earth turns over every 24 hours, we are carried with it through the points A, D, and B, *Fig.* 14; and, therefore, if a body is supposed to fall from the point A, say at 12 o'clock, and the same to fall again from the same point above the earth at 6 o'clock, the two lines of direction will be at right-angles, as represented in the figure, for that part of the earth which was under A at 12 o'clock, will be under D at 6 o'clock, the earth having in that time performed one quarter of its daily revolution. At 12 o'clock at night, if the body be supposed to fall again, its line of direction will be at right-angles with that of its last descent, and consequently, it will *ascend* in respect to the point from which it fell 12 hours before, because the earth would have then gone through one half her daily rotation, and the point A would be at B.

FIG. 14



Direction of Falling Bodies.

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105. How is this shown by Fig. 14? 106. Are the terms *up* and *down* relative or positive in their meaning? What is understood by *down* in any part of the earth? Suppose a ball be let fall at 12 and then at 6 o'clock, in what direction would the lines of their descent meet each other?

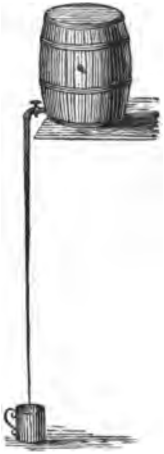
VELOCITY OF FALLING BODIES.

107. *The velocity of every falling body is uniformly accelerated in its approach toward the earth, from whatever height it falls.*

108. If a rock is rolled from a steep mountain, its motion is at first slow and gentle; but, as it proceeds downward, it moves with perpetually increased velocity, seeming to gather fresh speed every moment, until its force is such that every obstacle is overcome.

109. The principle of increased velocity as bodies descend from a height, is curiously illustrated by pouring molasses or thick syrup from an elevation to the ground. The bulky stream, *Fig.* 15, of perhaps two inches in diameter where it leaves the vessel, as it descends, is reduced to the size of a straw, or knitting-needle; but what it wants in bulk is made up in velocity, for the small stream at the ground will fill a vessel just as soon as the large one at the outlet.

FIG. 15.



Increased Velocity.

110. It is found, by experiment, that the motion of a falling body is accelerated in regular mathematical proportions.

These increased proportions do not depend on the increased weight of the body, because it approaches nearer the center of the earth, but on the constant operation of the force of gravity, which perpetually gives new impulses to the falling body, and increases its velocity.

111. It has been ascertained, by experiment, that a body falling freely, and without resistance, passes through a space of 16 feet and 1 inch during the first second of time. Leaving out the inch, which is not necessary for our present purpose, the ratio of descent is as follows:

112. If the height through which a body falls in one second of time be known, the height which it falls in any proposed time may be computed. For since the height is proportional to the square of the time, the height through which it will fall in *two* seconds will be *four* times that which it falls through in *one* second. In *three* seconds it will fall through *nine* times that

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107. What is said concerning the motions of falling bodies? 108. How is this increased velocity illustrated? 109. Explain Fig. 15. 110. What number of feet does a falling body pass through in the first second? 111. If a body fall from a certain height in two seconds, what proportion to this will it fall in four seconds?

space; in *four* seconds *sixteen* times that of the first second; in *five* seconds *twenty-five* times, and so on in this proportion.

The following, therefore, is a general rule to find the height through which a body will fall in any given time.

113. *Rule.—Reduce the given time to seconds; take the square of the number of seconds in the time, and multiply the height through which the body falls in one second by that number, and the result will be the height sought.*

114. The following table exhibits the height in feet, and the corresponding times in seconds.

Time	1	2	3	4	5	6	7	8	9	10
Height	1	4	9	16	25	36	49	64	81	100

Now, as the body falls at the rate of 16 feet during the first second, this number, according to the rule, multiplied by the square of the time, that is, by the numbers expressed in the second line, will show the actual distance through which the body falls.

115. Thus we have for the *first* second 16 feet; for the end of the *second;* $4\times16=64$ feet; *third*, $9\times16=144$; *fourth*, $16\times16=256$; *fifth*, $25\times16=400$; *sixth*, $36\times16=576$; *seventh*, $49\times16\times784$; and for the 10 seconds 1,600 feet.

116. If, on dropping a stone from a precipice, or into a well, we count the seconds from the instant of letting it fall until we hear it strike, we may readily estimate the height of the precipice, or the depth of the well. Thus, suppose it is 5 seconds in falling, then we only have to square the seconds, and multiply this by the distance the body falls in one second. We have then $5\times5=25$, the square, which $25\times16=400$ feet, the depth of the well.

117. Thus it appears, that to ascertain the velocity with which a body falls in any given time, we must know how many feet it fell during the first second: the velocity acquired in one second, and the space fallen through during that time, being the fundamental elements of the whole calculation, and all that are necessary for the computation of the various circumstances of falling bodies.

118. The difficulty of calculating exactly the velocity of a falling body from actual measurement of its height, and the time which it takes to reach the ground, is so great, that no accurate computation could be made from such an experiment.

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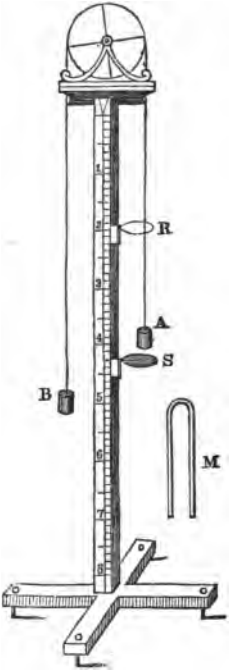
113. What is the rule by which the height from which a body falls may be found? 114. How many feet will a body fall in 10 seconds? 115. If the stone is 5 seconds in falling, how deep is the well?

119. **Atwood's Machine.**—This difficulty has, however, been overcome by a curious piece of machinery invented by Mr. Atwood. This consists of an upright pillar, with a wheel on the top, as shown by *Fig.* 16. The weights A and B are of the same size, and are made to balance each other exactly, being connected by a thread passing over the wheel. The ring, R, admits the weight, A, to fall through it in its passage to the stage, S, on which it rests. The ring and stage slide up and down, and are fastened by a thumb-screw. The pillar is a graduated scale, and M is a small bent wire, weighing a quarter of an ounce, and longer than the diameter of the ring.

FIG. 16.



Atwood's Machine.

120. When the machine is to be used, the weight, A, is drawn up to the top of the scale, and the ring and stage are placed a certain number of inches from each other. The small bar, M, is then placed across the weight, A, by means of which it is made slowly to descend. When it has descended to the ring, the small weight, M, is taken off by the ring, and thus the two weights are left equal to each other. Now it must be observed, that the motion and descent of the weight, A, are entirely owing to the gravitating force of the weight, M, until it arrives at the ring R, when the action of gravity is suspended, and the large weight continues to move downward to the stage, in consequence of the velocity it had acquired previously to that time.

121. To comprehend the accuracy of this machine, it must

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119. Is the velocity of a falling body calculated from actual measurement, or by a machine? 120. Describe the operation of Mr. Atwood's machine for estimating the velocities of falling bodies. 120. After the small weight is taken off by the ring, why does the large weight continue to descend? 121. Does his machine show the actual velocity of a falling body, or only its increase?

be understood that the velocities of gravitating bodies are supposed to be equal, whether they are large or small, this being the case when no calculation is made for the resistance of the air. Consequently, the weight of a quarter of an ounce placed on the large weight, A, is a representative of all other solid descending bodies. The slowness of its descent, when compared with freely gravitating bodies, is only a convenience by which its motion can be accurately measured, for it is the *increase* of velocity which the machine is designed to ascertain, and not the *actual* velocity of falling bodies.

122. Now it will be readily comprehended, that in this respect it makes no difference how slowly a body falls, *provided it follows the same law as other descending bodies*, and it has already been stated, that all estimates on this subject are made from the known distance a body descends during the first second of time.

123. It follows, therefore, that if it can be ascertained exactly, how much faster a body falls during the third, fourth, or fifth second, than it did during the first second, we should be able to estimate the distance it would fall during all succeeding seconds.

124. If, then, by means of a pendulum beating seconds, the weight, A, should be found to descend a certain number of inches during the first second, and another certain number during the next second, and so on, the ratio of acceleration would be precisely ascertained, and could be easily applied to the falling of other bodies; and this is the use to which this instrument is applied.

125. It will be readily conceived, that solid bodies falling from great heights, must ultimately acquire an amazing velocity by this proportion of increase.

126. By actual calculation, it has been found that were the moon to lose her projectile force, which counterbalances the earth's attraction, she would fall to the earth in four days and twenty hours, a distance of 240,000 miles. And were the earth's projectile force destroyed, it would fall to the sun, without resistance, in sixty-four days and ten hours, a distance of 95,000,000 of miles.

127. Every one knows, by his own experience, the different effects of the same body falling from a great, or small height.

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124. By what means is the ratio of descent found? 126. How long would it take the moon to come to the earth, according to the law of increased velocity? How long would it take the earth to fall to the sun? 127. What familiar illustrations are given of the force acquired by the velocity of falling bodies?

A boy will toss up his leaden bullet and catch it with his hand, but he soon learns, by its painful effects, not to throw it too high. The effects of hailstones on window-glass, animals, and vegetation, are often surprising, and some times calamitous illustrations of the velocity of falling bodies.

128. It has been already stated that the velocities of solid bodies, falling from a given height toward the earth, are equal, or in other words, that an ounce ball of lead will descend in the same time as a pound ball of lead.

This is true in theory, and in a vacuum, but there is a slight difference in this respect in favor of the velocity of the larger body, owing to the resistance of the atmosphere. We, however, shall at present consider all solids, of whatever size, as descending through the same spaces in the same times, this being exactly true when they pass without resistance.

129. To comprehend the reason of this, we have only to consider, that the attraction of gravitation in acting on a mass of matter, acts on every particle it contains; and thus every particle is drawn down equally, and with the same force. The effect of gravity, therefore, is in exact proportion to the quantity of matter the mass contains, and not in proportion to its bulk.

130. *Attraction proportionable to the quantity of matter.*—If, then, bodies attract each other in proportion to the quantities of matter they contain, it follows that if the mass of the earth were doubled, the weights of all bodies on its surface would also be doubled; and if its quantity of matter were tripled, all bodies would weigh three times as much as they do at present.

131. It follows, also, that two attracting bodies, when free to move, must approach each other mutually. If the two bodies contain like quantities of matter, their approach will be equally rapid, and they will move equal distances towards each other. But if the one be small and the other large, the small one will approach the other with a rapidity proportioned to the less quantity of matter it contains, as shown by the cork balls.

132. A man in a boat, pulling a rope attached to a ship, seems only to move the boat; but that he really moves the ship is certain, when it is considered that a thousand boats pulling in the same manner would make the ship meet them half way.

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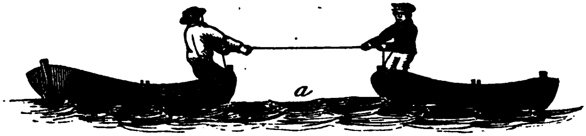
128. Will a small and a large body fall through the same space in the same time? **129.** On what parts of a mass of matter does the force of gravity act? Is the effect of gravity in proportion to bulk, or quantity of matter? **130.** Were the mass of the earth doubled, how much more should we weigh? **131.** Suppose one body moving toward another, three times as large, by the force of gravity what would be their proportional velocities? **132.** Does a large body attract a small one with any more force than it is attracted?

It appears, therefore, that an equal force acting on bodies containing different quantities of matter, moves them with different velocities, and that these velocities are in an inverse proportion to their quantities of matter.

133. In respect to *equal forces*, it is obvious that in the case of the ship and single boat, they were supposed to be moved toward each other by the same force, that is, the force of a man pulling by a rope. The same principle holds in respect to attraction, for all bodies attract each other equally, according to the quantities of matter they contain; and since all attraction is mutual, no body attracts another with a greater force than that by which it is attracted.

134. If, for example, two boats of equal size, be connected by a rope, and a man in one of them pulls with a force equal to 100 pounds, it is plain that the force on each vessel would be 100 pounds. For if the rope were thrown over a pully, and a man were to pull at one end with a force of 100 pounds, it is plain it would take 100 pounds at the other end to balance. See *Fig.* 17.

FIG. 17.



Attraction illustrated.

135. *Attracting bodies approach each other.*—It is inferred from the above principles, that all attracting bodies which are free to move, mutually approach each other, and therefore that the earth moves toward every body which is raised from its surface, with a velocity and to a distance proportional to the quantity of matter thus elevated from its surface. But the velocity of the earth being as many times less than that of the falling body as its mass is greater, it follows that its motion is not perceptible to us.

The following calculation will show what an immense mass of matter it would take, to disturb the earth's gravity in a perceptible manner.

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134. Suppose a man in one boat pulls with a force of 100 pounds at a rope fastened to another boat, what would be the force on each boat? How is this illustrated? 135. Do all attracting bodies approach each other? Suppose the body falls toward the earth, is the earth set in motion by its attraction? Why is not the earth's motion toward it perceptible?

136. If a ball of earth, equal in diameter to the tenth part of a mile, were placed at the distance of the tenth part of a mile from the earth's surface, the attracting powers of the two bodies would be in the ratio of about 512 millions of millions to one. For the earth's diameter being about 8,000 miles, the two bodies would bear to each other about this proportion. Consequently, if the tenth part of a mile were divided into 512 millions of millions of equal parts, one of these parts would be nearly the space through which the earth would move toward the falling body. Now, in the tenth part of a mile there are about 6,400 inches, consequently this number must be divided into 512 millions of millions of parts, which would give the eighty thousand millionth part of an inch through which the earth would move to meet a body the tenth part of a mile in diameter.

ASCENT OF BODIES.

137. Having now explained and illustrated the influence of gravity on bodies moving downward and horizontally, it remains to show how matter is influenced by the same power when bodies are thrown upward, or contrary to the force of gravity.

138. What has been stated in respect to the velocity of falling bodies is reversed in respect to those which are thrown upward; for, as the motion of a falling body is increased by the action of gravity, so it is retarded by the same force when projected from the center of gravity.

A bullet shot upward, every instant, loses a part of its velocity, until having arrived at the highest point from whence it was thrown, it then returns again to the earth.

139. The same law that governs a descending body, governs an ascending one, only that their motions are reversed.

140. The same ratio is observed to whatever distance the ball is propelled; for, as the height to which it is thrown may be estimated from the space it passes through during the first second, so its returning velocity is in a like ratio to the height to which it was sent.

141. This will be understood by *Fig.* 18. Suppose a ball to be propelled from the point A, with a force which would carry it to the point B in the first second, to C in the next, and to D in the third second. It would then remain nearly stationary for an

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136. What distance would a body, the tenth part of a mile in diameter, placed at the distance of a tenth part of a mile, attract the earth toward it? 138. What effect does the force of gravity have on bodies moving upward? 139. Are upward and downward motion governed by the same laws? 141. Explain Fig. 18. What is the difference between the upward and returning velocity of the same body?

instant; and, in returning, would pass through the same spaces in the same time, only that its direction would be reversed. Thus, it will fall from D to C in the first second, to B in the next, and to A in the third.

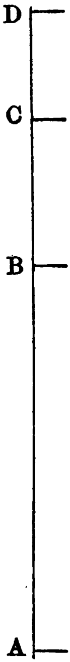
142. Now the momentum of a moving body is as its velocity and its quantity of matter; and, hence the same ball will fall with the same force that it rises. For instance, a ball shot out of a rifle, with force sufficient to overcome a certain impediment, on returning would again overcome the same impediment.

143. It has been doubted, even by good authority, whether the principle above enunciated is true; that is, whether a rising and a falling body observe the same law of motion, only, that they are reversed. On this point, we quote Dr. Lardner, who, perhaps, is not inferior to any other authority.

144. "All the circumstances attending the accelerated descent of falling bodies, are exhibited in a reversed order when a body is projected upward.

"Thus, if a body be projected vertically upward, with the velocity which it would acquire in falling freely during one second, the body so projected will rise exactly to the height from which it would have fallen in one second, and at that point of its ascent, it will have the velocity which it would have at the same point, if it had descended."—*Hand Book of Natural Philosophy*, (London, 1851,) p. 116.

FIG. 18.



145. It has been estimated that a leaden ball, falling from a sufficient height, would acquire a much greater force than if shot from a rifle.

It is understood that these estimates refer only to dense bullets, as those of lead, or other metals, on which the atmosphere has the least resistance.

146. It is stated that attempts have been made to test this principle by shooting rifle-balls vertically, and observing with what force they descended, by the depth they penetrated wooden impediments.

But, this would hardly be within the art of gunnery, unless the mark erected for the returning ball should be more extensive than experimenters would be willing to construct.

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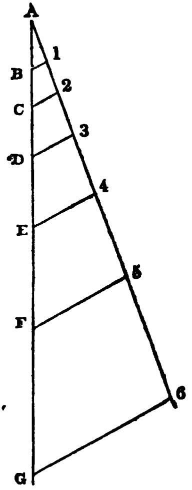
142. What is said of the returning force of a rifle-ball? 143. What doubts have been expressed on this subject? 144. What is the quotation from Dr. Lardner? 145. What estimates have been made with respect to the fall of a rifle-ball? 146. What is said of the experiment of shooting rifle-balls vertically?

MOTION ON INCLINED PLANES.

147. *Bodies falling down inclined planes follow the same laws of motion as those falling freely, only that their velocities are diminished in proportion as the planes are more or less inclined.*

148. This is illustrated by *Fig.* 19, where, let 1, 6, be an inclined plane, and A, G, the vertical line of the same length, the letters on each marking the points to which the falling body is supposed to reach in 1, 2, 3, 4, 5, and 6 seconds. Now suppose two balls to be dismissed at the same instant from A, the one falling freely, and the other along the plane. Then, to find the difference in their velocities, draw perpendicular lines from the points, 1, 2, 3, 4, 5, and 6, along the inclined plane, and extend these lines to B, C, D, E, F, G, of the vertical line, and these points will respectively mark the difference in their velocities. Thus, at the end of the first second, one of the balls will arrive at B, and the other at 1, and so in these proportions until they fall to the earth.

FIG. 19.



Fall on Inclined Plane.

149. It will, therefore, be observed, that, although the ball which falls down the plane is retarded in its motion by friction, still it follows the same law as the other; both being uniformly accelerated in their descent by the force of gravity.

FALL OF LIGHT BODIES.

150. *It has been stated that the earth's attraction acts equally on all bodies containing equal quantities of matter, and that in vacuo, all bodies whether large or small, descend from the same heights in the same time.*

There is, however, a great difference in the quantities of matter which bodies of the same bulk contain, and consequently a

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147. What are the laws of motion down inclined planes? 148. Explain Fig. 19. 149. What does the explanation of the figure prove? 150. What is said of the fall of bodies?

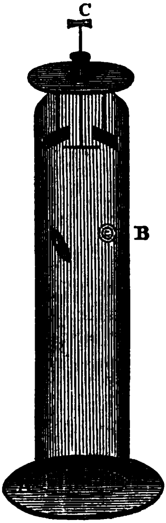
difference in the resistance which they meet with in passing through the air.

151. Now, the fall of a body containing a large quantity of matter in a small bulk, meets with little comparative resistance, while the fall of another, containing the same quantity of matter, but of larger size, meets with more in comparison, for two bodies of the same size meet with exactly the same resistance. Thus, if we let fall a ball of lead, and another of cork, of two inches in diameter each, the lead will reach the ground before the cork; because, though meeting with the same resistance, the lead has the greatest power of overcoming it.

152. This, however, does not affect the truth of the general law, already established, *that the weights of bodies are as the quantities of matter they contain.* It only shows that the pressure of the atmosphere prevents bulky and porous substances from falling with the same velocity as those which are compact or dense.

153. Were the atmosphere removed, all bodies, whether light or heavy, large or small, would descend with the same velocity. This has been ascertained, by experiment, as shown by *Fig.* 20.

FIG. 20.



Feather and Guinea.

The *air-pump* is an instrument by means of which the air can be pumped out of a close vessel, as will be seen under the article Pneumatics. Taking this for granted, at present, the experiment is made in the following manner:—

154. On the plate of the air-pump, A, place the tall jar, B, which is open at the bottom, and has a brass cover fitted closely to the top. Through the cover, let a wire pass, air-tight, having a small cross at the lower end. On each side of this cross, place a little stage, and so contrive them, that, by turning the wire by the handle, C, these stages shall be upset. On one of the stages place a guinea or piece of lead, and on the other place a feather. When this is arranged, let the air be exhausted from the jar by the pump, and then turn the handle, C, so that

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151. Why will not a sack of feathers and a stone of the same size fall through the air in the same time? 152. Does this affect the truth of the general law, that the weights of bodies are as their quantities of matter? 153. What would be the effect on the fall of light and heavy bodies, were the atmosphere removed? 154. How is it proved that a feather and a guinea will fall through equal spaces in the same time, where there is no resistance?

the guinea and feather may fall from their places, and it will be found that they will both strike the plate at the same instant. Thus is it demonstrated, that, were it not for the resistance of the atmosphere, a bag of feathers and one of guineas would fall from a given height with the same velocity, and in the same time.

CHAPTER III.

MOTION.

155. MOTION *may be defined, a continued change of place, with regard to a fixed point.*

156. Without motion, there would be no rising nor setting of the sun—no change of seasons—no fall of rain—no building of houses; and, finally, no animal life. Nothing can be done without motion; and, therefore, without it, the whole universe would be at rest, and dead.

157. In the language of philosophy, the power which puts a body in motion is called *force*. Thus, it is the force of gravity that overcomes the *inertia* of bodies, and draws them toward the earth. The force of water and steam gives motion to machinery, &c.

158. For the sake of convenience, and accuracy in the use of terms, motion is divided into two kinds, viz.: *absolute* and *relative.*

159. Absolute motion is a change of place with regard to a fixed point, and is estimated without reference to the motion of any other body. When a man rides along the street, or, when a vessel sails through the water, they are both in absolute motion.

160. Relative motion is a change of place in a body, with respect to another body, also in motion, and is estimated from that other body, exactly as absolute motion is from a fixed point.

161. The absolute velocity of the earth in its orbit, from west to east, is 68,000 miles in an hour; that of Mars, in the same direction, is 55,000 miles per hour. The earth's relative velocity,

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155. How will you define motion? **156.** What would be the consequence were all motion to cease? **157.** What is that power called which puts a body in motion? **158.** How is motion divided? **159.** What is absolute motion? **160.** What is relative motion? **161.** What is the earth's relative velocity in respect to Mars?

in this case, is 13,000 miles per hour, from west to east. That of Mars, comparatively, is 13,000 miles from east to west; because, the earth leaves Mars that distance behind her, as she would leave a fixed point.

162. *Rest*, in the common meaning of the term, is the opposite of motion; but, it is obvious that rest is often a relative term, since an object may be perfectly at rest with respect to some things, and in rapid motion in respect to others.

163. Thus, a man, sitting on the deck of a steamboat, may move at the rate of fifteen miles per hour, with respect to the land, and still be at rest with respect to the boat. And, so, if another man was running on the deck of the same boat, at the rate of fifteen miles the hour, in a contrary direction, he would be stationary, in respect to a fixed point, and still be running with all his might, with respect to the boat.

VELOCITY OF MOTION.

164. *Velocity is the rate of motion at which a body moves from one place to another.*

Velocity is independent of the weight or magnitude of the moving body. Thus, a cannon-ball and a musket-ball, both flying at the rate of a thousand feet in a second, have the same velocities.

165. Velocity is said to be *uniform*, when the moving body passes over equal spaces in equal times. If a steamboat moves at the rate of ten miles every hour, her velocity is uniform. The revolution of the earth from west to east is a perpetual example of uniform motion.

166. Velocity is *accelerated*, when the rate of motion is increased, and the moving body passes through unequal spaces in equal times. Thus, when a falling body moves sixteen feet during the first second, and forty-eight feet during the next second, and so on, its velocity is accelerated. A body falling from a height freely through the air, is the most perfect example of this kind of velocity.

167. *Retarded velocity*, is when the rate of motion of the body is constantly decreased, and it is made to move slower and slower. A ball thrown upward into the air, has its velocity constantly retarded by the attraction of gravitation; and, consequently, it moves slower every moment. (137.)

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162. What is rest? 163. In what respect is a man in a steamboat at rest, and in what respect does he move? 164. What is velocity? 165. When is velocity uniform? 166. When is velocity accelerated? Give illustrations of these two kinds of velocity. 167. What is meant by retarded velocity? Give an example of retarded velocity.

VELOCITIES OF CERTAIN MOVING BODIES.

168. Objects moving:—	Miles per hour.	Feet per second.
Man walking,	3	4½
Horse trotting,	7	10½
Swiftest race-horse,	60	88
Railway train. (English)	32	47
" (American)	18	26
" (Belgian)	25	36
" (French)	27	40
" (German)	24	35
Swift English steamers,	14	20
American steamers on the Hudson,	18	26
Fast sailing vessels,	10	14
Current of slow rivers,	3	4½
" of rapid rivers,	7	10
Moderate wind,	7	10
A storm, with wind,	36	52
A hurricane, in hot climates,	80	117
Air rushing into a vacuum,	884	1,296
Common musket-ball,	850	1,246
A rifle-ball,	1,000	1,466
A 24-lb. cannon-ball,	1,600	2,346
A bullet from an air-gun,	466	683
Sound, heat at 32°,	748	1,090
" do at 60°,	762	1,118
Earth's velocity round the sun,	67,374	98,815
" diurnal motion at equator,	1,037	1,520

169. The above, from Lardner's Mechanics, may be useful for occasional reference. We have omitted the fractional parts with respect to the seconds, as being difficult to remember, and useless for the present purpose. In regard to American locomotive speed, it is at the present time probably nearly one-third too small. The comparative velocities of balls from fire-arms differ from those given by some other authorities, but on this subject we have made no experiments.

FORCE, OR MOMENTUM OF MOVING BODIES.

170. *The velocities of bodies are equal, when they pass over equal spaces in the same times; but the force with which bodies, moving at the same rate, overcome impediments, is in proportion to the quantity of matter they contain.* This power, or force, is called the *momentum* of the moving body.

171. Thus, if two bodies of the same weight move with the same velocity, their momenta will be equal.

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168. What is said of the speed of our locomotives? 169. What is meant by the momentum of a body? 170. When will the momentum of two bodies be equal?

172. Two vessels, each of a hundred tons, sailing at the rate of six miles an hour, would overcome the same impediments or be stopped by the same obstructions. Their momenta would therefore be the same.

The force or momentum of a moving body, is in proportion to its quantity of matter, and its velocity.

173. A large body moving slowly, may have less momenta than a small one moving rapidly. Thus, a bullet shot out of a gun, moves with much greater force than a stone thrown by the hand.

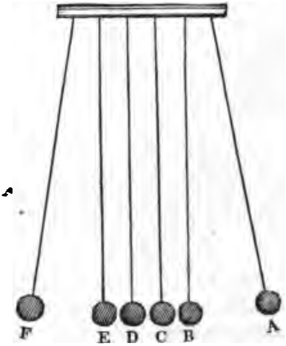
174. *The momentum of a body is found by multiplying its quantity of matter by its velocity per second.* Thus, if the velocity be 2, and the weight 2, the momentum will be 4. If the velocity be 6, and the weight of the body 4, the momentum will be 24.

175. If a moving body strikes an impediment, the force with which it strikes, and the resistance of the impediment, are equal. Thus, if a boy throw his ball against the side of the house, with the force of 3, the house resists it with an equal force, and the ball rebounds. If he throws it against a pane of glass with the same force, the glass having only the power of 2 to resist, the ball will go through the glass, still retaining one-third of its force.

176. ACTION AND REACTION EQUAL.—*From observations made on the effects of bodies striking each other, it is found that action and reaction are equal; or, in other words, that force and resistance are equal. Thus, when a moving body strikes one that is at rest, the body at rest returns the blow with equal force.*

This is illustrated by the well-known fact, that if two persons strike their heads together, one being in motion, and the other at rest, they are both equally hurt.

FIG. 21.



Action and Reaction.

177. The philosophy of

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172. Give an example. 173. When has a small body a greater momentum than a large one? 174. By what rule is the momentum of a body found? 175. When a moving body strikes an impediment, which receives the greatest shock? 176. What is the law of action and reaction? How is this illustrated?

action and reaction is finely illustrated by a number of ivory balls, suspended by threads, as in *Fig.* 21, so as to touch each other. If the ball A be drawn from the perpendicular, and then let fall, so as to strike the one next to it, the motion of the falling ball will be communicated through the whole series, from one to the other. None of the balls except F, will, however, appear to move. This will be understood, when we consider that the reaction of B is just equal to the action of A, and that each of the other balls, in like manner, act, and react, on the other, until the motion of A arrives at F, which, having no impediment, or nothing to act upon, is itself put in motion. It is therefore, reaction, which causes all the balls, except F, to remain at rest.

178. It is by a modification of the same principle, that rockets are impelled through the air. The stream of expanded air, or the fire which is emitted from the lower end of the rocket, not only pushes against the rocket itself, but against the atmospheric air, which, reacting against the air so expanded, sends the rocket along.

179. It was on account of not understanding the principles of action and reaction, that the man undertook to make a fair wind for his pleasure-boat, to be used whenever he wished to sail. He fixed an immense bellows in the stern of his boat, not doubting that the wind from it would carry him along. But on making the experiment, he found that his boat went backward instead of forward. The reason is plain. The reaction of the atmosphere on the stream of wind from the bellows, before it reached the sail, moved the boat in a contrary direction.

180. Had the sail received the whole force of the wind from the bellows, the boat would not have moved at all, for then, action and reaction would have been exactly equal, and it would have been like a man's attempting to raise himself over a fence by the straps of his boots.

181. The principle in question is beautifully illustrated by *Fig.* 22. It consists of a kind of stocking, supported by whalebone, which in swimming, contracts around the ankle as the foot is drawn up, but opens like an umbrella, thus acting with force, on the water, as the foot is pushed backward, precisely like the foot of a duck in the water.

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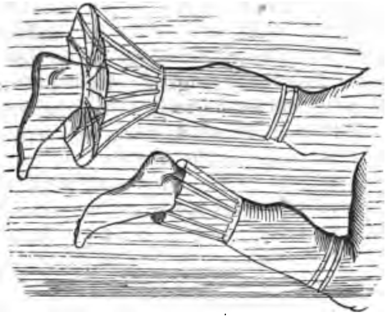
177. When one of the ivory balls strikes the other, why does the most distant one only move? 178. On what principle are rockets impelled through the air? 179. In the experiment with the boat and bellows, why did the boat move backward? 180. Why would it not have moved at all had the sail received all the wind from the bellows? 181. Explain Fig. 22.

FIG. 22.



Swimming Stocking.

REFLECTED MOTION.

182. *It has been stated* (22) *that all bodies when once set in motion, would continue to move straight forward, until some impediment, acting in a contrary direction, should bring them to rest; continued motion without impediment being a consequence of the inertia of matter.*

183. Such bodies are supposed to be acted upon by a single force, and that in the direction of the line in which they move. Thus, a ball sent out of a gun, or struck by a bat, turns neither to the right nor left, but makes a curve toward the earth, in consequence of another force, which is the attraction of gravitation, and by which, together with the resistance of the atmosphere, it is finally brought to the ground.

The kind of motion now to be considered, is that which is produced when bodies are turned out of a straight line by some force, independent of gravity.

184. A single force, or impulse, sends the body directly forward, but another force, not exactly coinciding with this, will give it a new direction, and bend it out of its former course.

185. If, for instance, two moving bodies strike each other obliquely, they will both be thrown out of the line of their former direction. This is called *reflected* motion, because it observes the same laws as reflected light.

186. The bounding of a ball; the skipping of a stone over the smooth surface of a pond; and the oblique direction of an

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182. What is said of the continuity of motion? 183. Suppose a body is acted on, and set in motion by a single force, in what direction will it move? 184. What is the motion called, when a body is turned out of a straight line by another force? 185. What illustrations can you give of reflected motion?

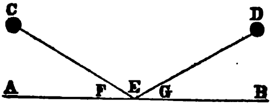
apple, when it touches a limb in its fall, are examples of reflected motion.

By experiments on this kind of motion, it is found that moving bodies observe certain laws, in respect to the direction they take in rebounding from any impediment they happen to strike.

187. Thus, a ball, striking on the floor, or wall of a room, makes the same angle in leaving the point where it strikes, that it does in approaching it.

188. Suppose A, B, *Fig.* 23, to be a marble floor, and C, to be an ivory ball, which has been thrown toward the floor in the direction of the line C, E; it will rebound in the direction of the line E D, thus making the two angles F and G exactly equal.

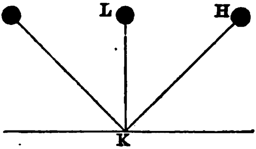
FIG. 23.



Reflected Motion.

189. If the ball approaches the floor under a larger or smaller angle, its rebound will observe the same rule. Thus, if it fell in the line H K, *Fig.* 24, its rebound would be in the line K I, and if it was dropped perpendicularly from L to K, it would return in the same line to L. The angle which the ball makes with the perpendicular line, L K, in its approach to the floor, is called the *angle of incidence*, and that which it makes in departing from the floor with the same line, is called the *angle of reflection*, and these angles are always equal.

FIG. 24.



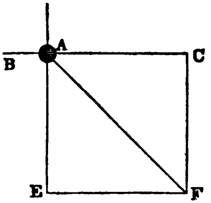
Equal Angles.

COMPOUND MOTION.

190. *Compound motion is that which is produced by two or more forces, acting in different directions, on the same body, at the same time.* This will be readily understood by a diagram.

191. Suppose the ball A, *Fig.* 25, to be moving with a certain velocity in the line B C, and suppose that at

FIG. 25.



Compound Motion.

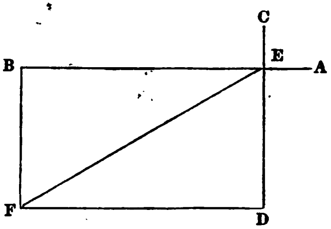
What laws are observed in reflected motion? 187. Suppose a ball to be thrown on the floor in a certain direction, what rule will it observe in rebounding? 188. Explain Fig. 23. 189. What is the angle called, which the ball makes in approaching the floor? What is the angle called, which it makes in leaving the floor? What is the difference between these angles? 190. What is compound motion? 191. Suppose a ball, moving with a certain force, to be struck crosswise with the same force, in what direction will it the instant when it came to the point A, it should be struck with an equal force in the direction of A E, then, as it can not obey the direction of both these forces, it will take a course between them, and fly off in the direction of F.

The reason of this is plain. The first force would carry the ball from B to C; the second would carry it from A to E; and these two forces being equal, gives it a direction just half way between the two, and therefore it is sent toward F.

The line A F, is called the *diagonal of the square.* and results from the cross forces, B and E, being equal to each other. If one of the moving forces is greater than the other, then the diagonal line will be lengthened in the direction of the greater force, and instead of being the diagonal of a square, it will become that of a parallelogram.

192. Suppose the force in the direction of A B, should drive the ball with twice the velocity of the cross force C D, *Fig.* 26, then the ball would go twice as far from the line C D, as from the line B A, and E F would be the diagonal of a parallelogram whose length is double its breadth.

FIG. 26.



Diagonal Motion.

193. Suppose a boat, in crossing a river, is rowed forward at the rate of four miles an hour, and the current of the river is at the same rate, then the two cross forces will be equal, and the line of the boat will be the diagonal of a square, as in *Fig.* 25. But if the current be four miles an hour, and the progress of the boat forward only two miles an hour, then the boat will go down the stream twice as fast as she goes across the river, and her path will be the diagonal of a parallelogram, as in *Fig.* 26, and therefore, to make the boat pass directly across the stream, it must be rowed toward some point higher up the river than the landing-place; a fact well known to boatmen.

194. Circus Rider.—Those who have seen feats of horsemanship at the circus, are often surprised that when the man leaps directly upward, the horse does not pass from under him,

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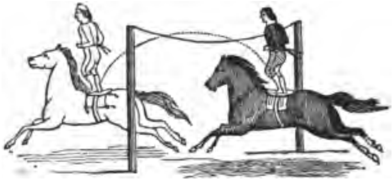
192. Suppose it to be struck with twice its former force, in what direction will it move? What is the line A F, Fig. 25 called? What is the line E F, Fig. 26, called? How are these figures illustrated? Explain Figs. 25 and 26. 193. Explain the motion of the boat? 194. Why does the leaping circus rider form the diagonal of a parallelogram?

and that in descending he does not fall behind the animal. But it should be considered that, on leaving the saddle, the body of the rider has the same velocity as that of the horse; nor does his leaving the horse by jumping upward, in any degree diminish his velocity in the same direction; his motion being continued by the impulse he had gained from the animal. In this case, the body of the man describes the diagonal of a parallelogram, one side of which is in the direction of the horse's motion, and the other perpendicularly upward, in the direction in which he makes the leap.

195. This will be better understood by *Fig.* 27, where the two forces are illustrated. Had the rider remained on the horse, he would have reached that point, where he meets him after the leap over the iron bar, under which the animal passes. This force the rider gains from the horse. The diagonal force is the result of his own muscular exertion, and by which he raises himself above the bar, still retaining in his leap the velocity of the horse, and thus regains the saddle, as though he had not left it.

FIG. 27.



Circus Rider.

The motion of the rider is through the section of a sphere, as shown by the figure, where the horse and rider are seen before and after the leap.

CIRCULAR MOTION.

196. *Circular motion is that of a body in a ring, or circle, and is produced by the action of two forces. By one of these forces, the moving body tends to fly off in a straight line, while by the other it is drawn toward the center, and thus it is made to revolve, or move round in a circle.*

197. The force by which a body tends to go off in a straight line, is called the *centrifugal force;* that which keeps it from flying away, and draws it toward the center, is called the *centripetal force.*

198. Bodies moving in circles are constantly acted upon by

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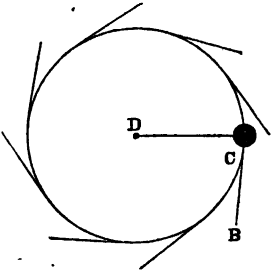
195. Explain Fig. 27, and show on what principle the rider meets his horse after the leap? 196. What is circular motion? How is this motion produced? 197. What is the centrifugal force? What is the centripetal force?

these two forces. If the centrifugal force should cease, the moving body would no longer perform a circle; but, would approach the center of its own motion. If the centripetal force should cease, the body would instantly begin to move off in a straight line; this being, as we have explained, the direction which all bodies take when acted on by a single force.

199. Suppose a cannon-ball, *Fig.* 28. tied with a string to the center of a slab of smooth marble, and suppose an attempt be made to push this ball with the hand in the direction of B; it is obvious that the string would prevent its going to that point; but would keep it in the circle. In this case the string is the *centripetal* force.

FIG. 28.



Centrifugal Force.

200. Now, suppose the ball to be kept revolving with rapidity, its velocity and weight would cause its centrifugal force; and, if the string were cut, when the ball was at the point C, for instance, this force would carry it off in the line toward B.

The greater the velocity with which a body moves round in a circle, the greater will be the force with which it would tend to fly off in a right line.

Thus, when one wishes to sling a stone to the greatest distance, he makes it whirl round with the greatest possible rapidity, before he lets it go. Before the invention of other warlike instruments, soldiers threw stones in this manner, with great force and dreadful effects.

201. The line about which a body revolves, is called its *axis of motion.* The point round which it turns, or, on which it rests, is called the *center of motion.* In *Fig.* 28, the point D, to which the string is fixed, is the center of motion. In the spinning-top, a line through the center of the handle to the point on which it turns, is the *axis of motion.*

202. *Revolution of a wheel.*—In the revolution of a wheel, that part which is at the greatest distance from the axis of mo-

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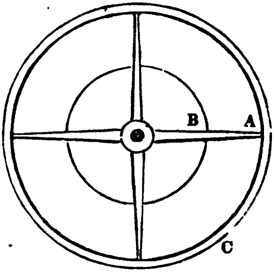
198. Suppose the centrifugal force should cease, in what direction would the body move? Suppose the centripetal force should cease, where would the body go? 199. What constitutes the centrifugal force of the body moving round in a circle? 200. How is this illustrated? 201. What is the axis of motion? What is the center of motion? Give illustrations.

tion, has the greatest velocity, and, consequently, the greatest centrifugal force.

FIG. 29.



Revolving Wheel.

Suppose the wheel, *Fig.* 29, to revolve a certain number of times in a minute, the velocity of the end of the arm at the point A, would be as much greater than its middle at the point B, as its distance is greater from the axis of motion, because it moves in a larger circle; and, consequently, the centrifugal force of the rim C, would, in like manner, be as its distance from the center of motion.

203. Large wheels, which are designed to turn with great velocity, must, therefore, be made with corresponding strength, otherwise the centrifugal force will overcome the cohesive attraction, or the strength of the fastenings, in which case the wheel will fly in pieces. This sometimes happens to the large grindstones used in gun factories, and the stone either flies away piecemeal, or breaks in the middle, to the great danger of the workmen.

204. Were the diurnal velocity of the earth about seventeen times greater than it is, those parts at the greatest distance from its axis would begin to fly off in straight lines, as the water does from a grindstone when it is turned rapidly.

CENTER OF GRAVITY.

205. *The center of gravity, in any body or system of bodies, is that point upon which the body, or system of bodies, acted upon only by gravity, will balance itself in all positions.*

206. The center of gravity, in a wheel made entirely of wood, and of equal thickness, would be exactly in its center of motion. But, if one side of the wheel were made of iron and the other part of wood, its center of gravity would be changed to some point aside from the center of the wheel.

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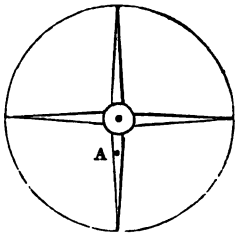
202. What part of a revolving wheel has the greatest centrifugal force? 203. Why must large wheels, turning with great velocity, be strongly made? 204. What would be the consequence, were the velocity of the earth seventeen times greater than it is? 205. Where is the center of gravity in a body? 206. Where is the center of gravity in a wheel made of wood? If one side is made of wood and the other of iron where is the center?

FIG. 30.



Center of Gravity.

207. Thus, the center of gravity in the wooden wheel, *Fig.* 30, is at the axis on which it turns; but, were the arm A of iron, its center of motion and of gravity would no longer be the same; but, while the center of motion remained as before, the center of gravity would fall to the point A. Thus, the center of motion and of gravity though often at the same point are not always so.

When a body is shaped irregularly, or there are two or more bodies connected, the center of gravity is the point on which they will balance without falling.

FIG. 31.

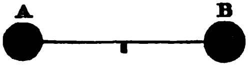
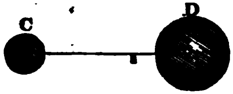


FIG. 32.



208. If the two balls, A and B, *Fig.* 31, weigh each four pounds, the center of gravity will be a point on the bar equally distant from each.

But, if one of the balls be heavier than the other, then the center of gravity will, in proportion, approach the larger ball. Thus, in *Fig.* 32, if C weighs two pounds, and D eight pounds, this center will be four times the distance from C that it is from D.

209. *Finding the Center of Gravity.*—In a body of equal thickness, as a board, or a slab of marble, but otherwise of an irregular shape, the center of gravity may be found by suspending it, first from one point, and then from another, and marking, by means of a plumb-line, the perpendicular ranges from the point of suspension. The center of gravity will be the point where these two lines cross each other.

Thus, if the irregular shaped piece of board, *Fig.* 33, be suspended by making a hole through it at the point A, and at the same point suspending the plumb-line C, both board and line will hang in the position represented in the figure. Having

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207. Is the center of motion and of gravity always the same? **208.** When two bodies are connected, as by a bar between them, where is the center of gravity? **209.** In a board of irregular shape, by what method is the center of gravity found?

FIG. 33.

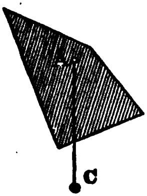


FIG. 34.

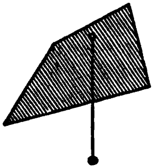
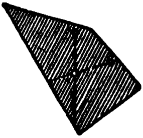


FIG. 35.



Finding the Center of Gravity.

marked this line across the board, let it be suspended again in the position of *Fig.* 34, and the perpendicular line again marked. The point where these lines cross is the center of gravity, as seen by *Fig.* 35.

210. *Importance of the subject.*—It is often of great consequence, in the concerns of life, that the subject of gravity should be well considered, since the strength of buildings, and of machinery, often depends chiefly on the gravitating point.

211. An upright object will fall to the ground, when it leans so much that a perpendicular line from its center of gravity falls beyond its base. A tall chimney, therefore, with a narrow foundation, such as are commonly built at the present day, will fall with a very slight inclination.

212. Now, in falling, the center of gravity passes through the part of a circle, the center of which is at the extremity of the base on which the body stands. This will be comprehended by *Fig.* 36.

FIG. 36.

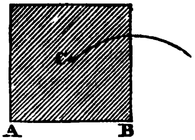
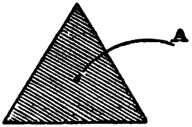


FIG. 37.



Suppose the figure to be a block of marble, which is to be turned over, by lifting at the corner A, the corner B would be the center of its motion, or the point on which it would turn. The center of gravity, C, would, therefore, describe the part of a circle, of which the corner, B, is the center.

213. It will be found that the greatest difficulty in turning

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210. Why is finding the center of gravity of importance? 211. In what direction must the center of gravity be from the outside of the base, before the object will fall? 212. In falling, the center of gravity passes through part of a circle; where is the center of this circle? 213. In turning over a body why does the force required constantly become less and less?

over a square block of marble, is in first raising up the center of gravity, for the resistance will constantly become less, in proportion as the point approaches a perpendicular line over the corner B, which, having passed, it will fall by its own weight.

The difficulty in turning over a body of a particular form, will be more strikingly illustrated by the figure of a triangle, or low pyramid.

214. In *Fig.* 37, the center of gravity is so low, and the base so broad, that in turning it over, a great proportion of its whole weight must be raised. Hence we see the firmness of the pyramid in theory, and experience proves its truth; for buildings are found to withstand the effects of time, and the commotions of earthquakes, in proportion as they approach this figure.

The most ancient monuments of the art of building, now standing, the pyramids of Egypt, are of this form.

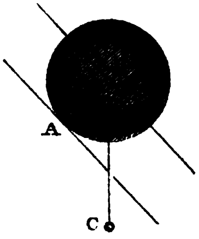
215. *Movement of a Ball.*—When a ball is rolled on a horizontal plane, the center of gravity is not raised, but moves in a straight line, parallel to the surface of the plane on which it rolls, and is consequently always directly over its center of motion.

216. If the plane is inclined downward, the ball is instantly thrown into motion, because the center of gravity then falls forward of that of motion, or the point on which the ball rests.

217. This is explained by *Fig.* 38, where A is the point on which the ball rests, or the center of motion, B the perpendicular line from the center of gravity, as shown by the plumb-weight C.

218. If the plane is inclined upward, force is required to move the ball in that direction, because the center of gravity then falls behind that of motion, and therefore this point has to be constantly lifted. This is also shown by *Fig.* 38, only considering the ball to be moving up the inclined plane, instead of down it.

FIG. 38.



From these principles, it will be readily understood why so much force is required to roll a heavy body, as a hogshead of sugar, for instance, up an inclined plane. The center of gravity falling behind that of motion, the

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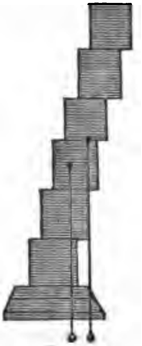
214. Why is there less force required to overturn a cube, or square, than a pyramid of the same weight? 215. If the plane is inclined downward, why does the ball roll in that direction? 217. Explain Fig. 38. 218. Why is force required to move a ball up an inclined plane.

weight is constantly acting against the force employed to raise the body.

219. *Illustration by Blocks.*—One of the best illustrations o. this subject may be made by a number of square blocks of wood, placed on each other, as in *Fig.* 39, forming a leaning tower. Where five blocks are placed in this position, the point of gravity is near the center of the third block, and is within the base, as shown by the plumb-line. But on adding another block, the gravitating point falls beyond the base, and the whole will now fall by its own weight.

FIG. 39.

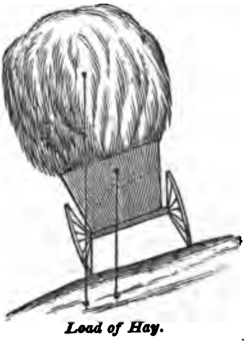


Leaning Tower.

220. The student having such blocks, (and they may be picked up about any joiner's shop,) will convince himself, that however carefully his leaning tower is laid up, it will not stand when the center of gravity falls an inch or two beyond the support.

221. We may learn, from these comparisons, that it is more dangerous to ride in a high carriage than a low one, in proportion to the elevation of the vehicle, and the nearness of the wheels to each other, or in proportion to the narrowness of the base, and the height of the center of gravity. A load of hay, *Fig.* 40, upsets where one wheel rises but little above the other, because it is broader on the top than the distance of the wheels from each other; while a load of stone is very rarely turned over, because the center of gravity is near the earth, and its weight between the wheels, instead of being far above them.

FIG. 40.



Load of Hay.

222. *Center of gravity in Man.*—In man the center of gravity is between the hips, and hence, were his feet tied together, and his arms tied by his sides, a very slight inclination of his body would carry the perpendicular of his center of

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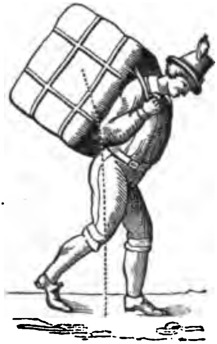
219. Why is a body, shaped like Fig. 39, easily thrown down? Hence, in riding in a carriage, how is the danger of upsetting proportioned? Explain Fig. 40. 220. How may the point of gravity be found by means of a number of square blocks? 221. Why will a load of hay upset more readily than one of stone? 222. Where is the center of man's gravity?

gravity beyond the base, and he would fall. But when his limbs are free to move, he widens his base, and changes this center at pleasure, by throwing out his arms, as circumstances require.

When a man runs, he inclines forward, so that the center of gravity may hang before his base, and in this position he is obliged to keep his feet constantly advancing, otherwise he would fall forward.

223. *Porter carrying a load.*—When a porter takes a load on his back, he instinctively regulates his center of gravity by leaning forward, so as to bring it in a line between his feet, as shown by *Fig.* 41.

FIG. 41.



Center of Gravity.

224. A man, standing with his heels against a perpendicular wall can not stoop forward without falling, because the wall prevents his throwing any part of his body backward. A person, little versed in such things, agreed to pay a certain sum of money for an opportunity of possessing himself of double the sum, by taking it from the floor with his heels against the wall. The man, of course, lost his money, for in such a posture, one can hardly reach lower than his own knee.

225. The base on which a man is supported, in walking or standing, is his feet, and the space between them. By turning the toes out, this base is made broader, without taking much from its length, and hence persons who turn their toes outward, not only walk more firmly, but more gracefully, than those who turn them inward.

226. By experience in the art of balancing, or of keeping the center of gravity in a line over the base, men sometimes perform things that, at first sight, appear altogether beyond human power, such as dining with the table and chair standing on a single rope, dancing on a wire, &c.

227. SHEPHERDS OF LANDES.—Men, as already noticed, by practice in the art of balancing, perform feats which are wonderful to all beholders. The shepherds of Landes, in the

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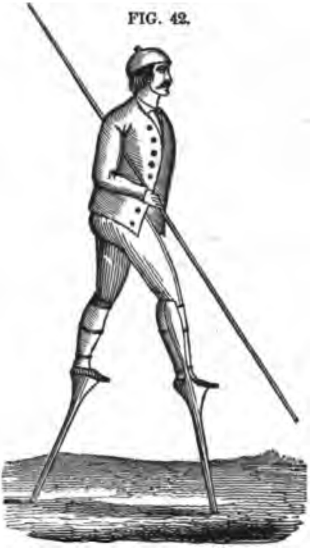
Why will a man fall with a slight inclination, when his feet and arms are tied? 223. Describe Fig. 41. 224. Why can not one who stands with his heels against a wall stoop forward? 225. Why does a person walk most firmly, who turns his toes outward? 226. In what does the art of balancing, or walking on a rope, consist?

south of France, are perhaps the only people who apply this art to the common business of life. These men walk on stilts from four to five feet high; and their children, when quite young, who are intended to take the places of their fathers as shepherds, are taught this art in order to qualify them for business.

FIG. 42.



Shepherd of Landes.

To strangers, passing their district, these men cut a figure at once ludicrous and surprising. *Fig.* 42. But, it is for their own convenience that this singular custom has been adopted; for, by this means the feet are kept out of the water which covers their land in the winter, and from the heated sand in the summer. Besides these comforts, the sphere of vision over a flat country is materially increased by the elevation, so that the shepherd can see his flock at a much greater distance than from the ground.

By habit, it is said these men acquire the art of balancing themselves so perfectly as to run, jump, and dance on these stilts with perfect ease. They walk with surprising quickness, so that footmen have to do their best to keep up with them.

CENTER OF INERTIA, OR INACTIVITY.

228. *It will be remembered that inertia* (22) *is one of the inherent or essential properties of matter, and that it is in consequence of this property, when bodies are at rest, that they never move without the application of force; and, when once in motion, that they never cease moving without some external cause.* (26.)

229. Now, inertia, though, like gravity, it resides equally in every particle of matter, must have, like it, a center in each particular body, and this center is the same with that of gravity.

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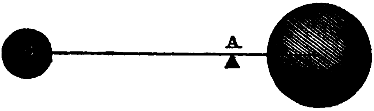
227. What principle is involved in Fig. 42. 228. What effect does inertia exert on bodies at rest? What effect does it have on bodies in motion? 229. Is the center of inertia and that of gravity the same?

230. In a bar of iron, six feet long and two inches square, this center is just three feet from each end, or exactly in the middle. If, therefore, the bar is supported at this point, it will balance equally; and, because there are equal weights on both ends, it will not fall.

FIG. 43.



Center of Inertia.

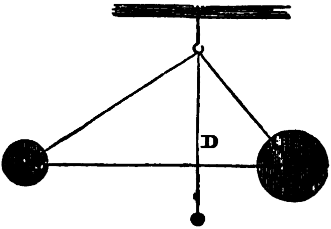
231. But, suppose the same bar of iron, whose inertia was overcome by raising the center, to have balls of different weights attached to its ends; then the center of inertia would no longer remain in the middle of the bar, but would be changed to the point A, *Fig.* 43, so that, to lift the whole, this point must be raised, instead of the middle, as before.

EQUILIBRIUM.

232. *When two forces counteract or balance each other, they are said to be in equilibrium.*

233. It is not necessary for this purpose that the weights opposed to each other should be equally heavy; for, we have just seen that a small weight, placed at a distance from the center of inertia, will balance a large one placed near it. To produce equilibrium, it is only necessary that the weights on each side of the support should mutually counteract each other; or, if set in motion, that their momenta should be equal.

FIG. 44.



Equilibrium.

234. A pair of scales are in equilibrium when the beam is in a horizontal position.

To produce equilibrium in solid bodies, therefore, it is only necessary to support the center of inertia or gravity.

235. If a body, or several bodies, connected, be suspended by a string, as in *Fig.* 44, the point of sup-

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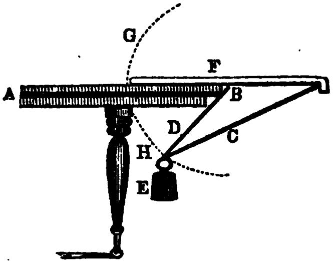
230. Where is the center of inertia in a body or a system of bodies? 231. Why is the point of inertia changed by fixing different weights to the ends of the iron bar? 232. What is meant by equilibrium? 233. To produce equilibrium, must the weights be equal? 234. When is a pair of scales in equilibrium? 235. When a body is suspended - a string, where must the support be with respect to the point of inertia?

port is always in a perpendicular line, above the center of inertia. The plumb-line, D, cuts the bar connecting the two balls at this point. Were the two weights in this figure equal, it is evident that the hook, or point of support, must be in the middle of the string, to preserve the horizontal position.

236. When a man stands on his right foot, he keeps himself in equilibrium by leaning to the right, so as to bring his center of gravity in a perpendicular line over the foot on which he stands.

237. In the complex arrangement shown by *Fig.* 45, equilibrium is preserved by the joint action of the two oblique forces, B and C. Place a walking-stick, F, on the edge of a table, so that it would fall if left to itself. Then fasten to its end the rod C, and, to the end of this, tie the cord D, which is also tied to the cane at B. Next, suspend the weight, E, in the place shown in the figure, so that it will hang a foot or two under the edge of the table, where, if all is right, it will remain as firmly as though it was tied to the table itself. In this case, the center of inertia is firmly supported by the table at F; and, therefore, it is not in danger of falling.

FIG. 45.



Equilibrium.

CURVILINEAR, OR BENT MOTION.

238. *We have seen that a single force acting on a body,* (190,) *drives it straight forward, and that two forces acting crosswise, drive it midway between the two, or give it a diagonal direction,* (192.)

Curvilinear motion differs from both these; the direction of the body being neither straight forward nor diagonal, but through a line which is curved.

This kind of motion may be in any direction; but, when it is produced in part by gravity, its direction is always toward the earth.

239. A stream of water from an aperture in the side of a vessel, as it falls toward the ground, is an example of a curved

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237. Explain Fig. 45. 238. What is meant by curvilinear motion? 239. What are examples of this kind of motion?

line; and, a body, passing through such a line, is said to have *curvilinear* motion. Any body projected forward, as a cannon-ball or rocket, falls to the earth in a curved line.

240. *In jets of water*, the shape of the curve will depend on the velocity of the stream. When the pressure of the water is great, the stream, near the vessel, is nearly horizontal; because its velocity is in proportion to the pressure. When a ball first leaves the cannon, it describes but a slight curve; because its projectile velocity is then greatest.

241. The curves described by jets of water under different degrees of pressure, are readily illustrated by tapping a tall vessel in several places, one above the other.

242. The action of gravity being always the same, the shape of the curve described must depend on the velocity of the moving body; but, whether the projectile force be great or small, the moving body, if thrown horizontally, will reach the ground from the same height in the same time.

This, at first thought, would seem improbable; for, without consideration, most persons would assert, that, if two cannons were fired from the same spot, at the same instant, and in the same direction, one of the balls falling half a mile, and the other a mile distant, that the ball which went to the greatest distance would take the most time in performing its journey.

243. But, the distance to which a ball will go depends on the force of impulse given it the first instant, and, consequently, on its projectile velocity. If it moves slowly, the distance will be short; if more rapidly, the space passed over will be greater. It makes no difference, then, in respect to the descent of the ball, whether its projectile motion be fast or slow, or whether it moves forward at all.

244. *Falling of Cannon Balls.*—This may be shown by experiment. Suppose a cannon to be loaded with a ball, and placed on the top of a tower, at such a height from the ground that it would take just four seconds for the ball to descend from it to the ground, if let fall perpendicularly. Now, suppose the cannon to be fired in an exact horizontal direction, and, at the same instant, the ball to be dropped toward the ground. They will both reach the ground at the same instant, provided its surface be a horizontal plane from the foot of the tower to the place where the projected ball strikes.

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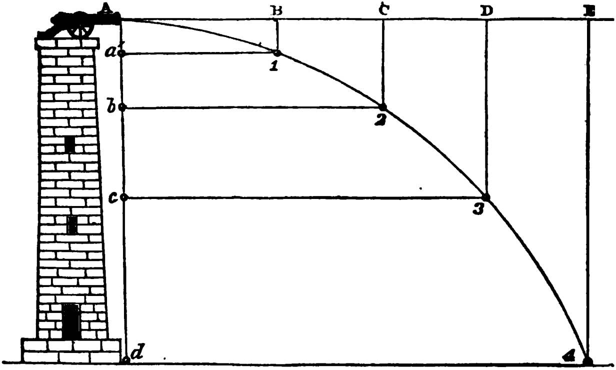
240. On what does the shape of the curve depend? **241.** How are the curves described by jets of water illustrated? **242.** What difference is there in respect to the time taken by a body to reach the ground, whether the curve be great or small? **243.** Does it make any difference in respect to the descent of the ball whether it has a projectile motion or not? **244.** Suppose, then, one ball be fired from a cannon, and another let fall from the same height, at the same instant, would they both reach the ground at the same time?

245. *Demonstration.*—This is demonstrated by *Fig.* 46, where A is the cannon from which the ball is to be fired, A the vertical line of the descending ball, A, B, 1, *a*, the parallelogram through which the ball passes during the first second.

Now the ball dropped in the vertical direction, will descend 16 feet the first second, increasing its velocity according to the law of falling bodies already explained. Meantime the projected ball passing through the diagonal of the upper parallelogram, will arrive at 1, while the other falls to *a*. During the next second the vertical ball will fall to *b*, while the other, in consequence of its projectile force, will pass through the diagonal of the parallelogram *b*, 2, C, A.

The same laws of descent being continued, it is obvious, that the two balls will reach *d*, 4, at the same instant.

FIG. 46.



Path of a Cannon Ball

246. From these principles, it may be inferred that the horizontal motion of a body through the air, does not interfere with its gravitating motion toward the earth; and, therefore, that a rifle-ball, or any other body, projected horizontally, will reach the ground in the same period of time as one that is let fall perpendicularly from the same height.

247. The two forces, acting on bodies which fall through curved lines, are the same as the centrifugal and centripetal

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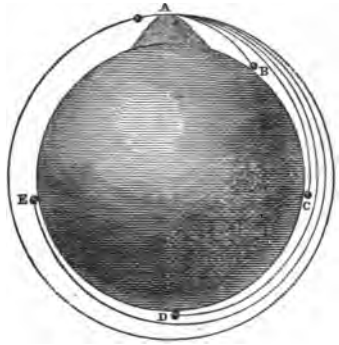
245. Explain Fig. 46, showing the reason why the two balls will reach the ground at the same time. Why does the ball approach the earth more rapidly in the last part of the curve than in the first part? 246. What is the inference from these principles? 247 What is the force called which throws a ball forward?

forces, already explained; the centrifugal, in the case of the ball, being caused by the powder; the centripetal, being the action of gravity, (199.)

248. *Perpetual Revolution.*—If a projectile be thrown from an elevated situation, it is plain that it would strike at a greater distance than if thrown on a level; because it would remain longer in the air. Every one knows that he can throw a stone to a greater distance when standing on a steep hill than when standing on the plain below.

FIG. 47.



Perpetual Revolution of a Ball.

249. Suppose the circle, *Fig.* 47, to be the earth, and A, a high mountain on its surface. Suppose that this mountain reaches above the atmosphere, or is fifty miles high; then a cannon-ball might perhaps reach from A to B, a distance of eighty or a hundred miles; because the resistance of the atmosphere being out of the calculation, it would have nothing to contend with except the attraction of gravitation. If, then, one degree of force, or velocity, would send it to B, another would send it to C; and, if the force was increased three times, it would fall to D; and, if four times, it would pass to E. If, now, we suppose the force to be about ten times greater than that with which a cannon-ball is projected, it would not fall to the earth at any of these points, but would continue its motion until it again came to the point A, the place from which it was first projected.

250. It would now be in equilibrium, the centrifugal force being just equal to that of gravity; and, therefore, it would perform another and another revolution, and so continue to revolve around the earth perpetually.

251. It is these two forces which retain the heavenly bodies

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248. What is that called which brings it to the ground? 249. Suppose the velocity of a cannon-ball, shot from a mountain 50 miles high, to be ten times its usual rate, where would it stop? Explain Fig. 47. 250. When would this ball be in equilibrium? Why would not the force of gravity ultimately bring this ball to the earth? 251. After the first revolution, if the two forces continue the same, would not the motion of the ball be perpetual?

in their orbits; and, in the case we have supposed, our cannon-ball would become a little satellite, moving perpetually round the earth.

GUNNERY.

252. LAW AND FORCE OF PROJECTILES.—Ever since the discovery of gunpowder, the laws of projectiles have been studied with attention, as being of importance in the art of war. Many learned and elaborate works have been published on the subject, but our limits will only admit the insertion of a few of the most important principles of Gunnery.

253. A projectile, as a bullet from a gun, unless it has a vertical direction, is acted on by two forces, that of projection, which carries it forward, and that of gravity, which draws it downward. Its path, therefore, is a curve, called a *parabola.*

254. The distance to which the ball will fly depends on the force of projection; since, if its direction is horizontal, its fall toward the earth by the force of gravity (249) will be the same, whether its velocity be great or small.

255. The resistance of the atmosphere, is the great impediment to the effects of projectile forces. Thus it has been demonstrated that a 24-lb. cannon-ball, discharged at an elevation of 45°, and at the velocity of 2,000 feet per second, would, in vacuo, reach the horizon-distance of 125,000 feet, but the resistance of the air limits its range to 7,300 feet.

256. VELOCITY OF THE BALL.—There are several methods of computing the velocity of the ball, one of which is by means of the *Ballistic pendulum.* This is a thick, heavy block of wood, so suspended as to swing freely about an axis, and into this the ball is fired. The weight of the ball and that of the block being known, the velocity is found by the degrees of motion given to the pendulum, which is accurately measured by machinery.

257. *Recoil of the Gun.*—Another method of finding the velocity of the ball, is by means of the recoil of the gun. This method is founded on the supposition that the explosive force of the powder communicates equal quantities of motion to the gun and ball, in opposite directions. Hence, by suspending the gun, loaded with weights, like a pendulum, the extent of its arc of vibration, will indicate the force of the charge, and by know-

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252. Why are the laws of projectiles viewed important? 253. What two forces act on projectiles? What is the path of a projectile called? 254. On what does the distance of a projectile depend? 255. What is said of atmospheric resistance? 256. What is the construction of the ballistic pendulum? 257. What is the other method of estimating the velocity of the ball?

ing the weights of the gun and ball, its velocity is indicated. By such means, Dr. Hutton constructed the following table :—

Powder.	Velocity per Second.	Distance.	Time of Flight.
Ounces.	Feet.	Feet.	Seconds.
2	800	4,100	9
4	1,230	4,100	12
8	1,640	6,000	14½
12	1,680	6,700	15½

258. Experiment shows that the velocity of the ball increases with the charge, to a certain extent, which is peculiar to each gun, after which, the increase diminishes the force, until the bore is quite full.

259. The greatest velocity of a ball known, is about 2,000 feet per second, and this from a cannon. This velocity diminishes, soon after it leaves the gun.

260. *Power and Destruction.*—The penetration of the ball is as the square of its velocity. Hence, when the object is merely to penetrate, as in the breaching of a fortification, the greatest velocity is given. But in naval combats, the utmost velocity is not the most injurious, the most destructive balls being such as merely pierce the ship's sides.

MANUFACTURE OF PERCUSSION CAPS.

261. The processes by which percussion caps are made at the establishment of Mr. McIntyre, in the city of Hartford, Ct., are as follow :—

262. *First.*—The copper is rolled to about the thickness of stout brown paper, and is then cut into strips three-fourths of an inch wide, and several yards long. The end of such a strip being placed between the rollers of a cutting and punching machine, invented for this purpose, the whole, without further attention, is cut into star-like pieces of the form and size represented by *Fig.* 48, A being the piece cut out, and B, the appearance of the strip of copper after the operation.

These pieces are instantly moved, by the same engine, under the punch, by which they are driven through a finely creased die, and are thus formed into caps which fall into a vessel below.

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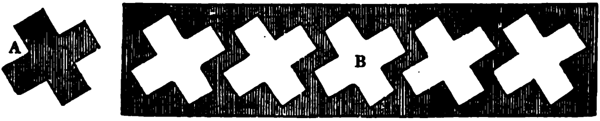
259. How far does the velocity of the ball increase with that of the charge ? 260. What is the greatest velocity of a ball ? 261. What velocity of the ball is most destructive ?

FIG. 48.



First shape of the Copper.

These stellate pieces, being struck by the punch in the center, the extremities are thus brought into contact, but not joined, so that the caps consist of four portions connected at the bottom, like the four quarters of an orange peel.

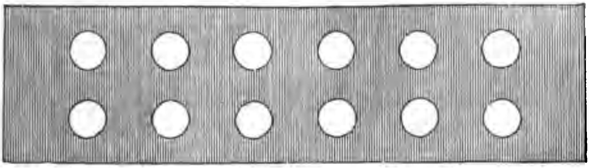
When the caps are exploded by the hammer, these quarters open and thus prevent the tearing of the metal which, if solid, would be apt to fly into fragments and thus endanger the eyes.

263. *Second.*—The caps are next placed in a revolving cylinder containing saw-dust, by which they are made clean and bright.

They are now ready to receive the *fulminating powder*, the explosion of which sets fire to the powder in the gun-barrel.

The caps are now placed, a handful at a time, on a sheet of iron, three feet long, eight inches wide, and the fourth of an inch thick, pierced with holes a quarter of an inch apart, as shown by *Fig.* 49. This being placed in a horizontal position, and shaken, the caps find their way into the apertures, with their open ends up, in a manner that is quite surprizing.

FIG. 49.

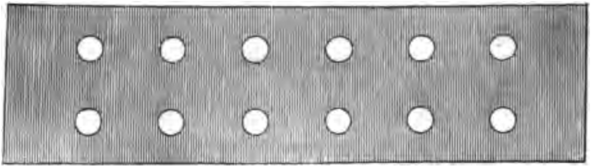


Mode of placing the Caps for Filling.

264. *Third.*—A piece of brass plate, of the exact size of that containing the caps, is pierced with apertures to correspond with each and every cap, but smaller in size, as shown by *Fig.* 50.

This plate, being about the sixth of an inch thick, is laid on

FIG. 50.



Mode of Filling.

a smooth surface, and the fulminating compound, a little moistened by gum-water, is rubbed into the apertures with the hand, where it adheres, that remaining on the surface being rubbed off.

265. *Fourth.*—This brass plate, being laid on that containing the caps, each aperture corresponding to a cap, the powder, by means of a brush, is made to fall into the caps.

266. *Fifth.*—The caps are now charged with the powder, in a loose state, and requires a gentle pressure to fix it in its place.

This is done by placing the plate, containing them, as above described, under rows of punches, which are worked with a little cam engine, and by which the punches are lifted, while the plate is moved forward, by means of a click and notches, so as to correspond exactly with the fall of the punches, by the pressure of which, the powder is fixed in its place.

267. *Sixth.*—The best caps are varnished, in order to protect them from moisture. It being the powder only which requires this protection, in France it is done with a little brush on each cap held in the fingers. But Mr. McIntyre has invented a much more expeditious way, and which insures the same quantity in each cap.

This is done by a small machine, consisting of two cams; a click working in horizontal notches, and a crank, by which the whole is moved. On the platform or bed of this, is laid the plate, *Fig.* 49, containing the caps, (263,) and on working the machine, two dozen blunt metallic points are alternately dipped into a little trough containing copal varnish, and then into the caps, these being moved by the click, to correspond with the revolution of the cams by which the motions of these points are produced. In this way hundreds of caps are varnished in a few minutes.

268. *Seventh.*—The edges of the best caps are polished,

one at a time, by holding them with pliers for a second on a spindle of steel, revolving a thousand times a minute, the point of which enters the cap, the edge rubbing against a shoulder, by which the work is done.

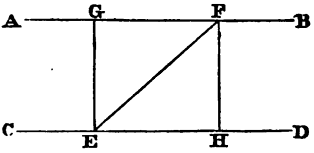
With two engines, as above described, the proprietor estimates the number of caps made per day, to be about 100,000, a market being always ready for all he can make.

RESULTANT MOTION.

269. *Resultant motion consists in the operation of two, or more, forces, the joint action of which, results in unity of effect.*

270. *Apple thrown from one boat to the other.*—Suppose two men to be sailing in two boats, each at the rate of four miles an hour, at a short distance opposite to each other, and suppose as they are sailing along in this manner, one of the men throws the other an apple. In respect to the boats, the apple would pass directly across from one to the other, that is, its line of direction would be at right-angles with the sides of the boats. But its actual line through the air would be oblique, or diagonal, in respect to the sides of the boats, because, in passing from boat to boat, it is impelled by two forces, viz., the force of the motion of the boat forward, and the force by which it is thrown by the hand across this motion.

FIG. 51.



Diagonal Motion.

271. *Resultant motion.*—This diagonal motion of the apple is called the *resultant*, or the resulting motion, because it is the effect or result of two motions resolved into one. Perhaps this will be more clear by *Fig.* 51, where A B, and C D, are supposed to be the sides of the two boats, and the line E F, that of the apple. Now the apple, when thrown, has a motion with the boat at the rate of four miles an hour, from C toward D, and this motion is supposed to continue just as though it had remained in the boat.

272. Had it remained in the boat during the time it was passing from E to F, it would have passed from E to H. But

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269. What is meant by resultant motion? Suppose two boats sailing at the same rate and in the same direction, if an apple be tossed from one to the other, what will be its direction in respect to the boats? What would be its line through the air in respect to the boats? 274. What is this kind of motion called? Why is it called resultant motion? Explain Fig. 51. 272. Why would the line of the apple be actually at right-angles in respect to the boats, but oblique in respect to parallel lines drawn from where it was thrown and where it struck? How is this further illustrated?

we suppose it to have been thrown at the rate of eight miles an hour, in the direction toward G; and if the boats are moving south, and the apple thrown toward the east, it would pass in the same time twice as far toward the east as it did toward the south. Therefore, in respect to the boats the apple would pass at right-angles from the side of one to that of the other, because they are both in motion. But in respect to a right line, drawn from the point where the apple was thrown, and a parallel line with this, drawn from the point where it strikes the other boat, the line of the apple would be oblique.

273. On the above principle, if two ships, during a battle, are sailing before the wind at equal rates, the aim of the gunners will be exactly the same as though they stood still; whereas, if the gunner fires from a ship standing still at another under sail, he takes his aim forward of the mark he intends to hit; because the ship would pass a little forward while the ball is going to her.

274. And, so, on the contrary, if a ship in motion fires at another standing still, the aim must be behind the mark; because, as the motion of the ball partakes of that of the ship, it will strike forward at the point aimed at.

275. For the same reason, if a ball be dropped from the topmast of a ship under sail, it partakes of the motion of the ship forward, and will fall in a line with the mast, and strike the same point on the deck as though the ship stood still.

It is on this principle that, if a cannon-ball be shot up vertically from the earth, it will fall back to the same point; for, although the earth moves forward while the ball is in the air, yet, as it carries this motion with it, so the ball moves forward, also, in equal degree, and, therefore, comes down at the same place.

HOROLOGY.

276. *This term, derived from the Greek, means, to indicate the hour. It is the science of time-keeping.*

277. For this purpose, a great variety of instruments have been invented, by some of which time was measured by the dropping of water, as in the *clepsydra*, or water-clock; in others, by the running of sand, as in the hour-glass, or by the revolution of the sun, by means of the *gnomon*, or sun-dial. But,

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273. When the ships are in equal motion, where does the gunner take his aim? Why does he aim forward of the mark when the other ship is in motion? 274. If a ship in motion fires at one standing still, where must be the aim? Why, in this case, must the aim be behind the mark? 275. What other illustrations are given of resultant motion? 276. What is the meaning of horology? 277. What were the ancient methods of keeping time?

these ancient methods have given place to the modern invention of clocks, regulated by the *pendulum*, and watches, regulated by a *balance-wheel.*

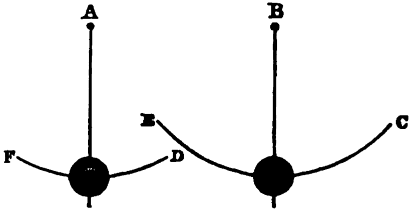
PENDULUM.

278. *A pendulum is a heavy body, such as a piece of brass or lead, suspended by a wire or cord, so as to swing backward and forward.*

When a pendulum swings, it is said to *vibrate;* and, that part of a circle through which it vibrates, is called its *arc.*

279. The times of the vibration of a pendulum are very nearly equal, whether it pass through a greater or less part of its arc.

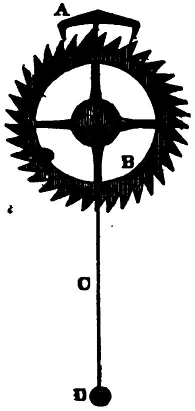
FIG. 52.



Pendulum.

Suppose A and B, *Fig.* 52, to be two pendulums of equal length, and suppose the weights of each are carried, the one to C, and the other to D, and both let fall at the same instant; their vibrations would be equal in respect to time, the one passing through its arc from C to E, and so back again in the same time that the other passes from D to F, and back again.

FIG. 53.



Common Clock.

280. The reason of this appears to be, that when the pendulum is raised high, the action of gravity draws it more directly downward, and it therefore acquires in falling a greater comparative velocity than is proportioned to the trifling difference of height.

281. *Common Clock.*—In the common clock, the pendulum is connected with wheel-work, to regulate the motion of the hands, and with weights or springs, by which the whole is moved. The number of vibrations which a

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278. What is a pendulum? 279. What is meant by the vibration of a pendulum? What is that part of a circle called through which it swings? 280. Why does the pendulum vibrate in equal time whether it goes through a small or large part of its arc?

pendulum makes in a given time depends upon its length; because a long pendulum does not perform its journey to and from the corresponding points of its arc so soon as a short one.

The parts concerned in the prime movements of the clock are shown by *Fig.* 53, of which A is the *escapement*, B the *crown-wheel*, C the *pendulum-rod*, and D the *weight.*

282. As the motion of the clock is regulated entirely by the pendulum, and as the number of vibrations are as its length, the least variation in this respect will alter its rate of going. To beat seconds, its length must be about thirty-nine inches. In the common clock, the length is regulated by a screw, which raises and lowers the weight. But, as the rod to which the weight is attached is subject to variations of length, in consequence of the change of the seasons, being contracted by cold and lengthened by heat, the common clock goes faster in winter than in summer.

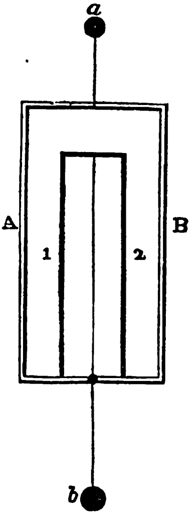
In the small clocks of the present day, the pendulum oscillates twice, and sometimes more, in a second, and consequently the crown-wheel must have sixty or more teeth, the second-hand performing two or more revolutions in a minute.

The length of a pendulum beating two seconds is the square of that beating seconds. If the length of the seconds pendulum be 39¼ inches, then that beating two seconds will be about 13 feet.

A pendulum beating half seconds is, in length, as the square root of that beating seconds, or about 10 inches long.

283. *Gridiron Pendulum.* — Various means have been contrived to counteract the effects of atmospheric changes, so that the pendulum may continue the same length the whole year. Among inventions for this purpose, the *gridiron* pendulum is considered among the best. It is so called, because it consists of several rods of different metals, connected together at each end.

FIG. 54.



Gridiron Pendulum.

284. The principle on which this pendulum is constructed is derived from the fact

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281. On what depends the number of vibrations which a pendulum makes in a given time? What is the medium length of the pendulum beating seconds? Why does a common clock go faster in winter than in summer? What is necessary in respect to the pendulum to make the clock go true the year round? 283. What is the principle on which the gridiron pendulum is constructed?

that some metals dilate more by the same degrees of heat than others. Thus, brass will dilate about twice as much by heat, and, consequently, contract twice as much by cold, as steel. If, then, these differences could be made to counteract each other mutually, given points at each end of a system of such rods would remain stationary the year round; and, thus the clock would go at the same rate in all climates, and during all seasons.

285. Suppose, then, the steel bars A B are firmly fixed to cross-bars at each end, as seen by *Fig.* 54, and that on the lower cross-bar, the brass rods 1 2 are also fixed, then the steel bars can expand only downward, and the brass ones only upward. Now, as the pendulum rod passes through the lower cross-bar, and is fixed to the upper cross-piece of the brass rods, it will be seen that the elongation of the two metals by heat mutually counteract each other; and, therefore, that the point of suspension, *a*, and the pendulum-weight, *b*, will always remain at the same distance from each other. It is found by experiment that the expansion of brass to that of steel is in the proportion of 100 to 61.

286. *Gravity varies the Vibrations.*—As it is the force of gravity which draws the weight of the pendulum from the highest point of its arc downward, and, as this force increases or diminishes as bodies approach toward the center of the earth, or recede from it, so the pendulum will vibrate faster or slower in proportion as this attraction is stronger or weaker.

287. Now, it is known that the earth at the equator rises higher from its center than it does at the poles; for, toward the poles it is flattened. The pendulum, therefore, being more strongly attracted at the poles than at the equator, vibrates more rapidly. For this reason, a clock that would keep exact time at the equator would gain time at the poles; for, the rate at which a clock goes depends on the number of vibrations its pendulum makes. Therefore, pendulums, in order to beat seconds, must be shorter at the equator, and longer at the poles.

For the same reason, a clock which keeps exact time at the foot of a high mountain, would move slower on its top.

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284. What are the metals of which this instrument is made? 285. Explain Fig. 54, and give the reason why the length of the pendulum will not change by the variations of temperature. 286. What is the downward force which makes the pendulum vibrate? Explain the reason why the same clock would go faster at the poles and slower at the equator. 287. How can a clock, which goes true at the equator, be made to go true at the poles? Will a clock keep equal time at the foot and on the top of a high mountain? Why will it not?

CHAPTER IV.

MECHANICS.

288. *Mechanics is a science which investigates the laws and effects of force and motion.*

289. The practical object of this science is to teach the best modes of overcoming resistance by means of mechanical powers, and to apply motion to useful purposes by means of machinery.

290. A *machine* is any instrument by which power, motion, or velocity, is applied or regulated.

291. A machine may be very simple, or exceedingly complex. Thus, a pin is a machine for fastening clothes, and a steam-engine is a machine for propelling mills and boats.

As machines are constructed for a vast variety of purposes, their forms, powers, and kinds of movement, must depend on their intended uses.

Several considerations ought to precede the actual construction of a new or untried machine; for, if it does not answer the purpose intended, it is commonly a total loss to the builder.

Many a man, on attempting to apply an old principle to a new purpose, or to invent a new machine for an old purpose, has been sorely disappointed; having found, when too late, that his time and money had been thrown away, for want of proper reflection, or requisite knowledge.

If a man, for instance, thinks of constructing a machine for raising a ship, he ought to take into consideration the *inertia* or *weight*, to be moved—the *force* to be applied—the *strength* of the materials, and the *space* or situation he has to work in. For, if the force applied, or the strength of the materials be insufficient, his machine is obviously useless; and, if the force and strength be ample, but the space be wanting, the same result must follow.

If he intends his machine for twisting the fibres of flexible substances into threads, he may find no difficulty in respect to power, strength of materials, or space to work in; but, if the *velocity*, *direction*, and kind of motion he obtains, be not applicable to the work intended, he still loses his labor.

Thousands of machines have been constructed, which, so far

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288. What is mechanics? 289. What is the object of this science? 290. What is a machine? 291. Mention one of the most simple, and one of the most complex of machines.

as regarded the skill of the workmen, the ingenuity of the contriver, and the construction of the individual parts, were models of art and beauty; and, so far as could be seen without trial, admirably adapted to the intended purpose. But, on putting them to actual use, it has too often been found that their only imperfection consisted in a stubborn refusal to do any part of the work intended.

Now, a thorough knowledge of the laws of motion, and the principles of mechanics, would, in many instances, at least, have prevented all this loss of labor and money, and spared him so much vexation and chagrin, by showing the projector that his machine would not answer the intended purpose.

The importance of this kind of knowledge is, therefore, obvious, and, it is hoped, will become more so as we proceed.

DEFINITIONS.

292. In mechanics, as well as in other sciences, there are words which must be explained, either because they are common words used in a peculiar sense, or because they are terms of art not in common use. All technical terms will be, as much as possible, avoided; but, still, there are a few which it is necessary here to explain.

293. *Force* is the means by which bodies are set in motion, kept in motion, and, when moving, are brought to rest. The force of gunpowder sets the ball in motion, and keeps it moving until the force of the resisting air, and the force of gravity, bring it to rest.

294. *Power* is the means by which the machine is moved, and the force gained. Thus, we have horse-power, water-power, and the power of weights.

295. *Weight* is the resistance, or the thing to be moved by the force of the power. Thus, the stone is the weight to be moved by the force of the lever or bar.

296. *Fulcrum*, or prop, is the point on which a thing is supported, and about which it has more or less motion. In raising a stone, the thing on which the lever rests is the fulcrum.

297. In mechanics, there are a few simple machines called the *mechanical powers*; and, however mixed or complex, a combination of machinery may be, it consists only of these few individual powers.

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293. What is meant by force in mechanics? 294. What is meant by power? 295. What is understood by weight? 296. What is the fulcrum? 297. Are the mechanical powers numerous, or only few in number?

We shall not here burden the memory of the pupil with the names of these powers, of the nature of which he is, at present, supposed to know nothing, but shall explain the action and use of each in its turn, and then sum up the whole for his accommodation.

MEASURES OF LENGTH.

298. In foreign books, we often meet with the names of measures which are unknown in this country. On this account, we insert the following:—

COMPARISON OF MEASURES OF DIFFERENT COUNTRIES.

	Foot.	Inches.	Lines.	Millimeters.
England and United States,	1 =	12 =	144 =	304
Prussia, (Rhenish foot),	1 =	12 =	144 =	313
Parisian foot,	1 =	12 =	144 =	324
Austria,	1 =	12 =	144 =	316
Hesse Darmstadt,	1 =	10 =	100 =	250
Saxony,	1 =	12 =	144 =	283
Frankfort,	1 =	12 =	144 =	284
Brunswick,	1 =	12 =	144 =	285
Hamburgh,	1 =	10 =	100 =	286
Hesse,	1 =	12 =	144 =	287
Bavaria,	1 =	12 =	144 =	291
Hanover,	1 =	12 =	144 =	291
Baden,	1 =	10 =	100 =	300

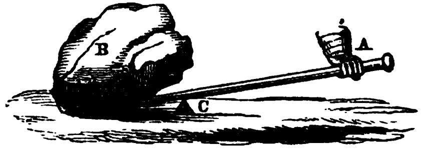
THE LEVER.

299. *Any rod or bar, which is used in raising a weight, or surmounting a resistance, by being placed on a fulcrum or prop, becomes a lever. Levers are simple and compound.*

300. *Simple levers* are of three kinds, namely: first, where the fulcrum is between the power and the weight; second, where the weight is between the fulcrum and the power; third, where the power is between the fulcrum and the weight.

301. *First Kind.*—The first kind is represented by *Fig.* 55, being a straight rod of iron, called a *crowbar*, in common use for raising rocks and other heavy bodies. The

FIG. 55.



Simple Lever.

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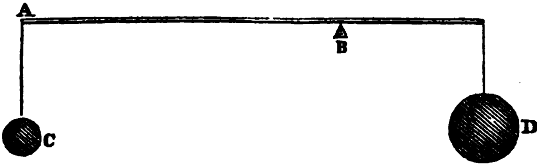
299. What is a lever? 300. What are the three kinds of simple levers? 301. What is the simplest of all mechanical powers? Explain Fig. 55.

stone, B, is the *weight*, A the *lever*, and C the *fulcrum;* the *power* being the hand of a man applied at A.

It will be observed, that, by this arrangement, the application of a small power may be used to overcome a great resistance.

302. The force to be obtained by the lever depends on its length, together with the power applied, and the distance of the weight and power from the fulcrum.

FIG. 56.

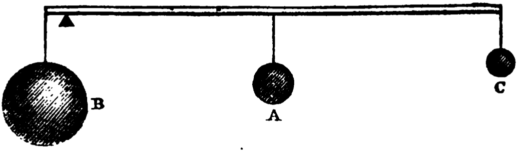


Lever—Unequal Arms.

303. Suppose, *Fig.* 56, that A is the lever, B the fulcrum, D the weight to be raised, and C the power. Let D be considered three times as heavy as C, and the fulcrum three times as far from C as it is from D; then the weight and power will exactly balance each other. Thus, if the bar be four feet long, and the fulcrum three feet from the end, then three pounds on the long arm will weigh just as much as nine pounds on the short arm, and these proportions will be found the same in all cases.

304. When two weights balance each other, the fulcrum is always at the center of gravity between them; and, therefore, to make a small weight raise a large one the fulcrum must be placed as near as possible to the large one, since, the greater the distance *from the fulcrum the small weight* or power is placed, the greater will be its force.

FIG. 57.



Lever—Double Weights.

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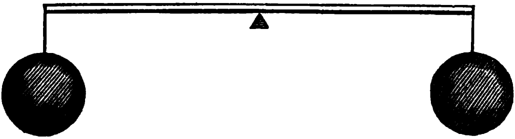
301. Which is the weight? Where is the fulcrum? Where is the power applied? What is the power in this case? 302. On what does the force to be obtained by the lever depend? 303. Suppose a lever four feet long, and the fulcrum one foot from the end, what number of pounds will balance each other at the ends? 304. When weights balance each other, at what point between them must the fulcrum be?

305. Suppose the weight B, *Fig.* 57, to be sixteen pounds, and suppose the fulcrum to be placed so near it as to be raised by the power A, of four pounds, hanging equally distant from the fulcrum and the end of the lever. If now the power A be removed, and another of two pounds, C, be placed at the end of the lever, its force will be just equal to A, placed at the middle of the lever.

306. But, let the fulcrum be moved along to the middle of the lever, with the weight of sixteen pounds still suspended to it, it would then take another weight of sixteen pounds, instead of two pounds, to balance it, *Fig.* 58.

FIG. 58.



Lever—Equal Arms.

Thus, the power which would balance sixteen pounds, when the fulcrum is in one place, must be exchanged for another power weighing eight times as much, when the fulcrum is in another place.

307. From these investigations, we may draw the following general truth, or proposition, concerning the lever: "*That the force of the lever increases in proportion to the distance of the power from the fulcrum, and diminishes in proportion as the distance of the weight from the fulcrum increases.*"

308. From this proposition, may be drawn the following rule, by which the exact proportions between the weight or resistance, and the power may be found. *Multiply the weight by its distance from the fulcrum; then multiply the power by its distance from the same point, and, if the products are equal, the weight and the power will balance each other.*

309. Suppose a weight of 100 pounds on the short arm of a lever, 8 inches from the fulcrum, then another weight or power, of 8 pounds, would be equal to this, at the distance of 100 inches from the fulcrum; because, 8 multiplied by 100 is equal

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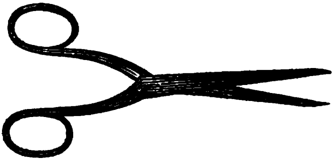
305. Suppose a weight of 16 pounds on the short arm of a lever is counterbalanced by 4 pounds in the middle of the long arm, what power would balance this weight at the end of the lever? **306.** Suppose the fulcrum to be moved to the middle of the lever, what power would then be equal to 16 pounds? **307.** What is the general proposition drawn from these results? **308.** What is the rule for finding the proportions between the weight and power? **309.** Give an illustration of this rule.

to 800; and, 100 multiplied by 8 is equal to 800, and, thus they would mutually counteract each other.

310. Many instruments in common use are on the principle of this kind of lever. Scissors, *Fig.* 59, consist of two levers, the rivet being the *fulcrum* for both. The fingers are the *power*, and the cloth to be cut the *resistance* to be overcome.

FIG. 59



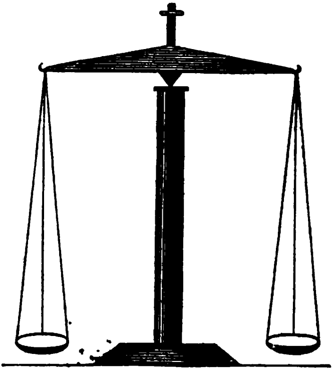
Two Levers.

Pincers, *forceps*, and *sugar-cutters*, are examples of this kind of lever.

311. A common *scale-beam*, used for weighing, is a lever, suspended at the center of gravity, so that the two arms balance each other. Hence, the machine is called a *balance*. The fulcrum, or what is called the *pivot*, is sharpened, like a wedge, and made of hardened steel, as much as possible to avoid friction.

312. A dish is suspended by cords to each end or arm of the lever, for the purpose of holding the articles to be weighed. When the whole is suspended on a point at the center, *Fig.* 60, the beam or lever ought to remain in a horizontal position, one of its ends being exactly as high as the other. If the weights in the two dishes are equal, and the support exactly in the center, they will always hang as represented in the figure.

FIG. 60.



Common Balance.

313. A very slight variation of the point of support toward one end of the lever, will make a difference in the weights employed to balance each other. In weighing a pound of sugar, with a scale-beam of eight inches long, if the point of

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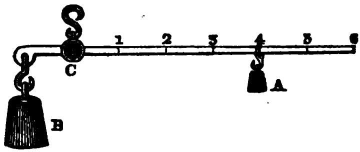
310. What instruments operate on the principle of this lever? 311. In the common scale-beam, where is the fulcrum? 312. In what position ought the scale-beam to hang? 313. How may a fraudulent scale-beam be made?

support is half an inch too near the weight, the buyer would be cheated nearly one ounce, and, consequently, nearly one pound in every sixteen pounds. This fraud might instantly be detected by changing the places of the sugar and weight; for, then, the difference would be quite material, since the sugar would then seem to want twice as much additional weight as it did really want.

314. The *steelyard* differs from the balance in having its support near one end, instead of in the middle, and also in having the weights suspended by hooks, instead of being placed in a dish.

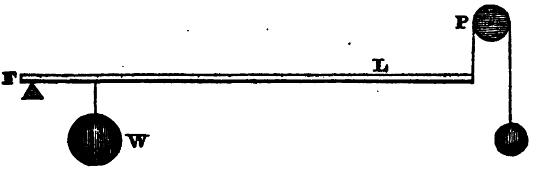
FIG. 61.



Steelyard.

If we suppose the beam to be 7 inches long, and the hook, C, *Fig.* 61, to be one inch from the end, then the pound weight A will require an additional pound at B for every inch it is moved from it. This, however, supposes that the bar will balance itself before any weights are attached to it.

FIG. 62.



Lever of the Second Kind.

315. *Second Kind.*—The second kind of lever is represented by *Fig.* 62, where W is the weight, L the lever, F the fulcrum, and P a pulley, over which a string is thrown, and a weight suspended, as the power. In the common use of a lever of the first kind, the force is gained by bearing down the long arm, which is called *prying.* In the second kind, the force is gained by carrying the long arm in a contrary direction, or upward, and this is called *lifting.*

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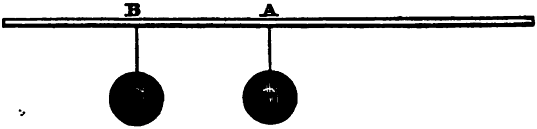
313. How may the cheat be detected? 314. How does the steelyard differ from the balance? 315. In the first kind of lever, where is the fulcrum, in respect to the weight and power? In the second kind, where is the fulcrum, in respect to the weight and power? What is the action of the first kind called? What is the action of the second kind called?

316. Levers of the second kind are not so common as the first, but are frequently used for certain purposes. The oars of a boat are examples of the second kind. The water, against which the blade of the oar pushes, is the fulcrum; the boat is the weight to be moved, and the hands of the man the power.

317. Two men, carrying a load between them on a pole, is also an example of this kind of lever. Each man acts as the power in moving the weight, and, at the same time, each becomes the fulcrum in respect to the other.

If the weight happens to slide on the pole, the man toward whom it goes has to bear more of it in proportion as its distance from him is less than before.

FIG. 63.

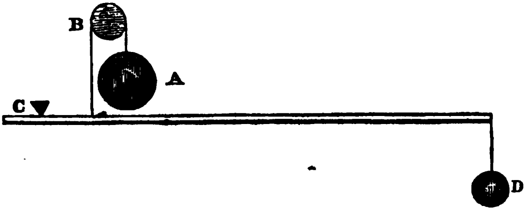


Lever—Unequal Arms.

318. A load at A, *Fig.* 63, is borne equally by the two men, being equally distant from each other; but, at B, three-quarters of its weight would be on the man at that end, because three-quarters of the length of the lever would be on the side of the other man.

319. *Third Kind.*—In the third and last kind of lever, the weight is placed at one end, the fulcrum at the other end, and the power between them; or, the hand is between the fulcrum and the weight.

FIG. 64.



Lever of the Third Kind.

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316. Give examples of the second kind of lever. 317. In rowing a boat, what is the fulcrum, what the weight, and what the power? 318. What other illustrations of this principle are given? 319. In the third kind of lever, where are the respective places of the weight, power, and fulcrum?

This is represented by *Fig.* 64, where C is the fulcrum, A the power, suspended over the pulley B, and D is the weight to be raised.

320. This kind of lever works to great disadvantage, since the power must be greater than the weight. It is, therefore, seldom used, except in cases where velocity and not force is required. In raising a ladder from the ground to the roof of a house, men are obliged sometimes to make use of this principle, and the great difficulty of doing so illustrates the mechanical disadvantage of this kind of lever.

We have now described the three kinds of levers, and, we hope, have made the manner in which each kind acts plain, by illustrations. But, to make the difference between them still more obvious, and, to avoid all confusion, we will here compare them together.

FIG. 65.

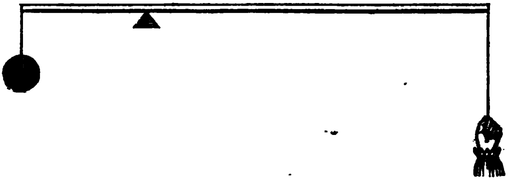
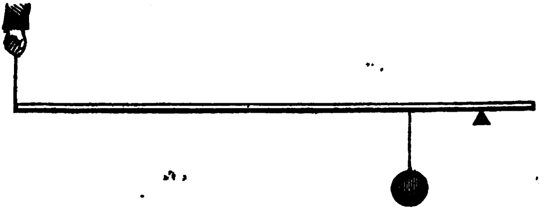


FIG. 66.



321. In *Fig.* 65, the weight and hand both act downward. In 66, the weight and hand act in contrary directions, the hand upward and the weight downward, the weight being between them. In 67, the hand and weight also act in contrary directions, but the hand is between the fulcrum and the weight.

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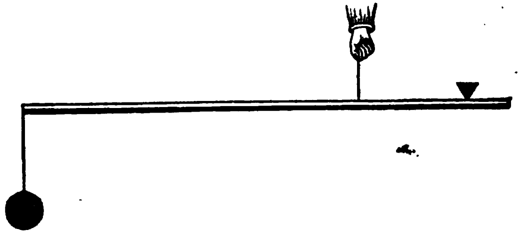
320. What is the disadvantage of this kind of lever? Give an example of the use of the third kind of lever. 321. In what direction do the hand and weight act, in the first kind of lever? In what direction do they act in the second kind In what direction do they act in the third kind?

FIG. 67.

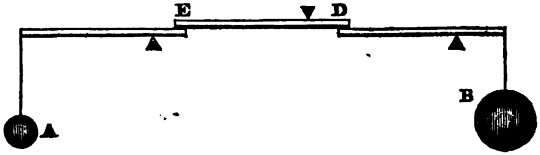


The Levers Compared.

322. COMPOUND LEVER.—When several simple levers are connected together, and act one upon the other, the machine is called a *compound lever*. In this machine, as each lever acts as an individual, and with a force equal to the action of the next lever upon it, the force is increased or diminished, and becomes greater or less in proportion to the number, or kind of levers employed.

We will illustrate this kind of lever by a single example, but must refer the inquisite student to more extended works for a full investigation of the subject.

FIG. 68.



Compound Lever.

Fig. 68 represents a compound lever, consisting of three simple levers of the first kind.

323. In calculating the force of this lever, the rule applies which has already been given for the simple lever, namely: *The length of the long arm is to be multiplied by the moving power, and that of the short one, by the weight, or resistance.*

324. Let us suppose, then, that the three levers in the figure are of the same length, the long arms being six inches,

---

322. What is a compound lever? 323. By what rule is the force of the compound lever calculated? 324. How many pounds weight will be raised by three levers connected, of six inches each, with the fulcrum two inches from the end, by a power of one pound?

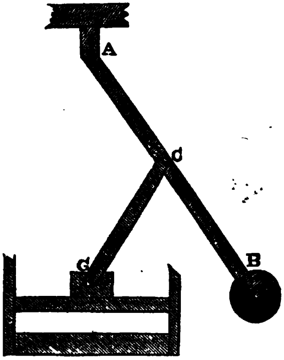
and the short ones two inches long; required, the weight which a moving power of 1 pound at A will balance at B. In the first place, 1 pound at A, would balance 3 pounds at E, for the *lever* being 6 inches, and the power 1 pound, 6×1=6, and the short one being 2 inches, 2×3=6. The long arm of the second lever being also 6 inches, and moved with a power of 3 pounds, multiply the 3 by 6=18; and multiply the length of the short arm, being 2 inches, by 9=18. These two products being equal, the power upon the long arm of the third lever, at D, would be 9 pounds. 9 pounds ×6=54, and 27×2, is 54; so that 1 pound at A would balance 27 at B.

The increase of force is thus slow, because the proportion between the long and short arms is only as 2 to 6, or in the proportions of 1, 3, 9.

325. Now suppose the long arms of these levers to be 18 inches, and the short ones 1 inch, and the result will be surprisingly different, for then 1 pound at A would balance 18 pounds at E, and the second lever would have a power of 18 pounds. This being multiplied by the length of the lever, 18×18=324 pounds at D. The third lever would thus be moved by a power of 324 pounds, which, multiplied by 18 inches for the weight it would raise, would give 5,831 pounds.

326. The compound lever is employed in the construction of *weighing machines*, and particularly in cases where great weights are to be determined, in situations where other machines would be inconvenient, on account of their occupying too much space.

FIG. 69.



Knee Lever.

327. **Knee Lever.**—A compound instrument, called the *Knee Lever*, is used in various kinds of machinery, the principle of which is explained by *Fig.* 69.

This combination consists of a metal rod, A B, having a joint at A, above which there is a firm support. At C is another rod, or bar,

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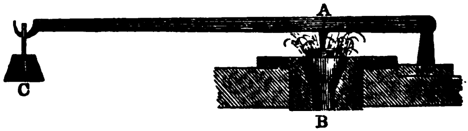
325. If the long arms of the levers be eighteen inches, and the short ones one inch, how much will a power of one pound balance? 326. In what machines is the compound lever employed? 327. Explain the principle of the Knee Lever, Fig. 69.

jointed to the long lever, and terminating at G, where there is still another joint, attached to a movable platform, on which the force of the two levers are exerted.

Now when B is pushed toward the vertical position, the force on the joints A and G, is constantly increased, until the two bars become perpendicular, when the pressure exerted, is augmented to nearly an indefinite degree.

328. Various engines for pressing paper, and for printing, are constructed on this principle, and it is said they are unequaled in power, except by the Hydrostatic press.

FIG. 70.



Safety-Valve Lever.

329. *Safety-valve Lever.* The application of the lever of the first kind, *Fig.* 70, for the purpose of indicating the pressure of steam, is common to all kinds of steam engines. The fulcrum A, of this lever is a point resting on the conical valve B, around which the steam passes, and the pressure of which, is indicated by the rising of the weight C. The length of the lever, and the number of pounds at C, shows the pressure on the square inch, this being the size of the valve.

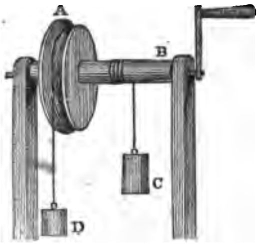
WHEEL AND AXLE.

330. The mechanical power, next to the lever in arrangement, is the *wheel and axle.* It is, however, much more complex than the lever.

331. It consists of two wheels, one of which is larger than the other; but the small one passes through the larger, and hence both have a common center, on which they turn.

332. The manner in which this machine acts will be understood by *Fig.* 71. The large wheel, A, on turning the machine, will take up, or throw off,

FIG. 71.



Wheel and Axle.

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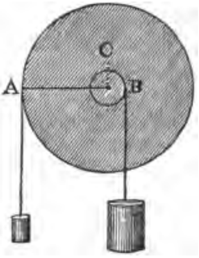
328. Explain Fig. 70. 329. What machines are on this principle? 330. What is the next mechanical power to the lever? 331. Describe this machine. 332. Explain Fig. 71

as much more rope than the small wheel or axle, B, as its circumference is greater. If we suppose the circumference of the large wheel to be four times that of the small one, then it will take up the rope four times as fast. And because A is four times as large as B, 1 pound at D will balance 4 pounds at C, on the opposite side.

333. The principle of this machine is that of the lever, as will be apparent by an examination of *Fig.* 72.

334. This figure represents the machine endwise, so as to show in what manner the lever operates. The two weights hanging in opposition to each other, the one on the wheel at A, and the other on the axle at B, act in the same manner as if they were connected by the horizontal lever A B, passing from one to the other, having the common center, C, as a fulcrum between them.

FIG. 72.



Wheel and Axle.

335. The wheel and axle, therefore, acts like a constant succession of levers, the long arm being half the diameter of the wheel, and the short one half the diameter of the axle; the common center of both being the fulcrum. The wheel and axle has, therefore, been called the *perpetual* lever.

336. The great advantage of this machanical arrangement is, that while a single lever of the same power can raise a weight but a few inches at a time, and then only in a certain direction, this machine exerts a continual force, and in any direction wanted. To change the direction, it is only necessary that the rope by which the weight is to be raised, should be carried in a line perpendicular to the axis of the machine, to the place below where the weight lies, and there be let fall over a pulley.

337. Suppose the wheel and axle, *Fig.* 73, is erected in the third story of a store-house, with the axle over the scuttles, or doors through the floors, so that goods can be raised by it from the ground-floor, in the direction of the weight A. Suppose, also, that the same store stands on a wharf, where ships come up to its side, and goods are to be removed from the vessels into the upper stories. Instead of removing the goods

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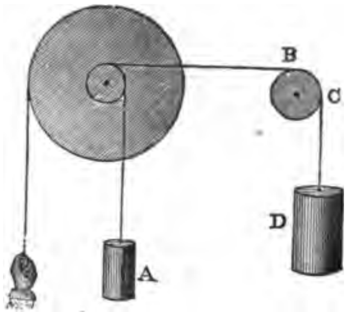
333. On what principle does this machine act? 334. In Fig. 72, which is the fulcrum, and which the two arms of the lever? 335. What is this machine called, in reference to the principle on which it acts? 336. What is the great advantage of this machine over the lever and other mechanical powers?

into the store, and hoisting them in the direction of A, it is only necessary to carry the rope B, over the pulley C, which is at the end of a strong beam projecting out from the side of the store, and then the goods will be raised in the direction of B, thus saving the labor of moving them twice.

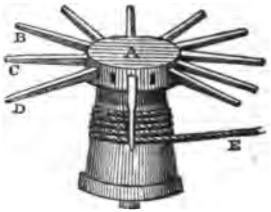
FIG. 73.



Modified Wheel and Axle.

The wheel and axle, under different forms, is applied to a variety of common purposes.

FIG. 74.



Capstan

338. The *capstan*, in universal use, on board of ships, is an axle placed upright, with a head, or drum, A, *Fig.* 74, pierced with holes for the levers B, C, D. The weight is drawn by the rope, E, passing two or three times round the axle to prevent its slipping.

339. This is a very powerful and convenient-machine. When not in use, the levers are taken out of their places and laid aside, and when great force is required, two or three men can push at each lever.

340. Windlass.—The *common windlass* for drawing water is another modification of the wheel and axle. The *winch*, or *crank*, by which it is turned, is moved around by the hand, and there is no difference in the principle, whether a whole wheel is turned, or a single spoke. The winch, therefore, answers to the wheel, while the rope is taken up, and the weight raised by the axle, as already described.

In cases where great weights are to be raised, and it is required that the machine should be as small as possible, on account of room, the wheel and axle, modified as represented by *Fig.* 75, is sometimes used.

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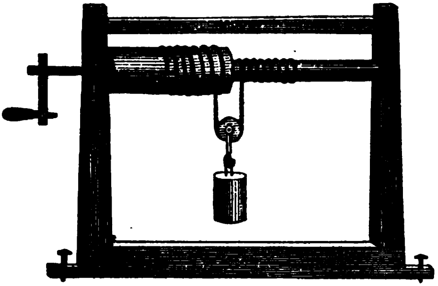
337. Describe Fig. 73, and point out the manner in which weights can be raised by letting fall a rope over the pulley. 338. What is the capstan? Where is it chiefly used? 339. What are the peculiar advantages of this form of the wheel and axle? 340. In the common windlass, what part answers to the wheel?

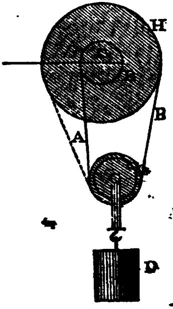
FIG. 75



Modified Windlass.

341. The axle may be considered in two parts, one of which is larger than the other. The rope is attached by its two ends, to the ends of the axle, as seen in the figure. The weight to be raised is attached to a small pulley, around which the rope passes. The elevation of the weight may be thus described. Upon turning the axle, the rope is coiled around the larger part, and at the same time, it is thrown off the smaller part. At every revolution, therefore, a portion of the rope will be drawn up, equal to the circumference of the thicker part, and at the same time a portion, equal to that of the thinner part, will be let down. On the whole, then, one revolution of the machine will shorten the rope where the weight is suspended, just as much as the difference is between the circumference of the two parts. The above frame is to be screwed to a platform.

FIG. 76.



Windlass.

342. *Illustration.*—Now to understand the principle on which this machine acts, we must refer to *Fig.* 76, where it is obvious that the two parts of the rope, A and B, equally support the weight D, and that the rope, as the machine turns, passes from the small part of the axle E to the large part H, consequently, the weight does not rise in a perpendicular line toward C, the center of both, but in a line between the outsides of the large and small parts.

343. Let us consider what would be

Explain Fig. 75. 341. Why is the rope shortened, and the weight raised? 342. What is the design of Fig. 76? Does the weight rise perpendicular to the axis of motion? 343. Suppose the cylinder was, throughout, of the same size, what would be the consequence?

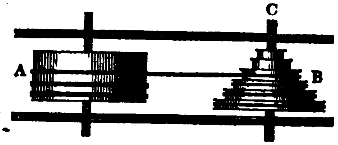
the consequence of changing the rope A to the larger part of the axle, so as to place the weight in a line perpendicular to the axis of motion. In this case, it is obvious that the machine would be in equilibrium, since the weight D would be divided between the two sides equally, and the two arms of the lever passing through the center C, would be of equal length, and therefore no advantage would be gained.

344. But in the actual arrangement, the weight being sustained equally by the large and small parts, there is involved a lever power, the long arm of which is equal to half the diameter of the large part, while the short arm is equal to half the diameter of the small part, the fulcrum being between them.

A varying Power, producing a Constant Force.—If a power varying under any given conditions, be required to overcome a resistance which varies according to some other given conditions, the one may be accommodated to the other by producing a variation in the leverage, by which one or both acts.

345. This is done in the mechanism of the watch, of which A, *Fig.* 77, is the *barrel* containing the power in the form of a convoluted spring, and B the *fusee* which acts as a varying lever, and through which motion is conveyed to the hands of the watch.

FIG. 77.



Barrel and Fusee.

346. Now when the watch is first wound up, the main-spring within the barrel is closely coiled, and of course acts with much more power than afterward, when it is partly unrolled; hence, were no means used to equalize this power, every watch would run two or three times as fast, when first wound up, as afterward.

347. We shall see that the fusee is a complete remedy for the varying action of the main-spring. Its form is a low cone, with its surface cut into a spiral groove, to receive the chain, which runs round the barrel. Now when the watch is wound up, by applying the key to the axis of the fusee at C, the main-spring, one end of which is attached to the diameter of the

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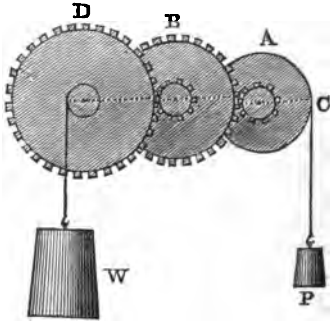
344. On what principle does this machine act? Which are the long and short arms of the lever, and where is the fulcrum? 345. What is the main-spring of a watch? 346. Where is it contained? What is the fusee of a watch? What is its form? When does the main-spring act with most force? 347. How does the fusee equalize this force? Explain how the forces of the spring and fusee mutually equalize each other.

barrel, and the other to its axis, is closely coiled; but as the action begins on the smallest part of the fusee, the leverage is short, and the power weak; but as the fusee turns, and the spring uncoils, the leverage increases in proportion as the strength of the spring becomes weaker, and thus the two forces mutually equalize each other, and the watch runs at the same rate until the chain which connects them has run from the barrel to the fusee, when it again requires winding, and the same process begins again.

348. System of Wheels.—*As the wheel and axle is only a modification of the simple lever, so a system of wheels acting on each other, and transmitting the power to the resistance, is only another form of the compound lever.*

FIG. 78.



System of Wheels.

349. Such a combination is shown in *Fig.* 78. The first wheel, A, by means of the teeth or cogs, around its axle, moves the second wheel, B, with a force equal to that of a lever, the long arm of which extends from the center to the circumference of the wheel, where the power P, is suspended, and the short arm from the same center to the ends of the cogs. The dotted line C, passing through the center of the wheel A, shows the position of the lever, as the wheel now stands. The center on which the wheel and axle turns, is the fulcrum of this lever. As the wheel turns, the short arm of this lever will act upon the long arm of the next lever by means of the teeth on the circumference of the wheel B, and this again through the teeth on the axle of B, will transmit its force to the circumference of the wheel D, and so by the short arm of the third lever to the weight W. As the power or small weight falls, therefore, the resistance W, is raised, with the multiplied force of three levers acting on each other.

350. In respect to the force to be gained by such a machine, suppose the number of teeth on the axle of the wheel A, to be

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348. On what principle does a system of wheels act, as represented in Fig. 78? **349** Explain Fig. 78, and show how the power P is transferred by the action of levers?

six times less than the number of those on the circumference of the wheel B, then B would only turn around once, while A turns six times. And, in like manner, if the number of teeth on the circumference of D, be six times greater than those on the axle of B, then D would turn once, while B is turning six times. Thus six revolutions of A would make B revolve once, and six revolutions of B would make D revolve once. Therefore, A makes thirty-six revolutions while D makes only one.

351. The diameter of the wheel A, being three times the diameter of the axle of the wheel D, and its velocity of motion being 36 to 1, 3 times 36 will give the weight which a power of 1 pound at P would raise at W. Thus 36 × 3 = 108. One pound at P would therefore balance 108 pounds at W.

352. NO MACHINE CREATES FORCE.—If the student has attended closely to what has been said on mechanics, he will now be prepared to understand, that no machine, however simple or complex, can *create* the least degree of force, it is true that a man with a machine may apply a force which a hundred could not exert with their hands, but then it would take him a hundred times as long.

353. Suppose there are 20 blocks of stone to be moved a hundred feet; perhaps twenty men, by taking each a block, would move them all in a minute. One man with a capstan, we will suppose, may move them all at once, but this man, with his lever, would have to make one revolution for every foot he drew the whole load toward him, and therefore to make one hundred revolutions to perform the whole work. It will also take him twenty times as long to do it, as it took the twenty men. His task, indeed, would be more than twenty times harder than that performed by the twenty men, for, in addition to moving the stone, he would have the friction of the machinery to overcome, which commonly amounts to nearly one third of the force employed.

354. Hence there would be an actual loss of power by the use of the capstan, though it might be a convenience for the one man to do his work by its means, rather than to call in nineteen of his neighbors to assist him.

355. Any power by which a machine is moved, must be equal to the resistance to be overcome, and, in all cases where the power descends, there will be a proportion between the

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351. What weight will one pound at P balance at W? 352. Is there any actual power gained by the use of machinery? 353. Suppose twenty men to move twenty stones to a certain distance with their hands, and one man moves them back to the same place with a capstan, which performs the most actual labor? Why? 354. Why, then, is machinery a convenience? 355. In the use of the lever, what proportion is there between the force of the short arm, and the velocity of the long arm? Is it said, that the velocity of the power downward, must be in proportion to that of the weight upward?

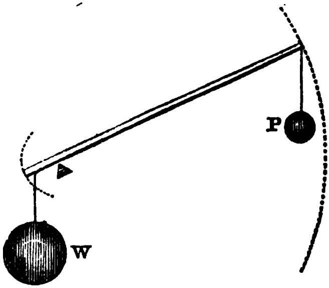
velocity with which it moves downward, and the velocity with which the weight moves upward.

356. There will be no difference in this respect, whether the machine be simple or compound, for if its force be increased by increasing the number of levers, or wheels, the velocity of the moving power must also be increased, as that of the resistance is diminished.

357. There being, then, always a proportion between the velocity with which the moving force descends, and that with which the weight ascends, whatever this proportion may be, it is necessary that the power should have to the resistance the same ratio that the velocity of the resistance has to the velocity of the power. In other words, "*The power multiplied by the space through which it moves, in a vertical direction, must be equal to the weight multiplied by the space through which it moves in a vertical direction.*

This law is known under the name of "the law of virtual velocities," and is considered the *golden rule* of mechanics.

FIG. 79.



Weight and Space.

358. This principle has already been explained, while treating of the lever, (308;) but that the student should want nothing to assist him in clearly comprehending so important a law, we will again illustrate it in a different manner.

Suppose the lever, *Fig.* 79, to be thirty inches long from the fulcrum to the point where the power, P, is suspended, and that the weight, W, is two inches from the fulcrum. If the power be 1 pound, the weight must be 15 pounds, to produce equilibrium, and the power, P, must fall thirty inches to raise the weight, W, two inches. Therefore, the power being 1 pound, and the space 30 inches, $30 \times 1 = 30$. The weight being 15 pounds, and the space 2 inches, $15 \times 1 = 30$.

Thus the power multiplied by the space through which it falls, and the weight multiplied by the space through which it rises, are equal.

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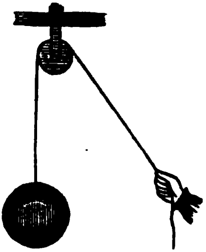
356. Does it make any difference, in this respect, whether the machine be simple or compound? 357. What is the golden rule of mechanics? Explain Fig. 79, and show how the rule is illustrated by it?

359. **However complex the machine may be, by which the force of a descending power is transmitted to the weight to be raised,(the same rule will apply as it does to the action of the simple lever.)**

THE PULLEY.

360. *A pulley consists of a wheel which is grooved on the edge, and which is made to turn on its axis, by a cord passing over it.*

FIG. 80.



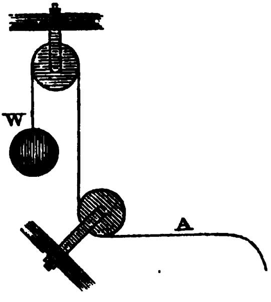
Simple Pulley.

361. *Simple Pulley,—Fig.* 80, represents a *simple pulley,* (with a single fixed wheel.) In other forms of the machine, the wheel moves up and down with the weight.

362. The pulley is arranged among the simple mechanical powers; but (when several are connected, the machine is called a *system of pulleys,* or a *compound pulley.*)

363. One of the most obvious advantages, of the pulley is, (its enabling men to exert their own power in places where they cannot go themselves.) Thus, by means of a rope and wheel, a man can stand on the deck of a ship, and hoist a weight to the topmast.

FIG. 81.



Simple Pulley.

364. By means of two fixed pulleys, a weight may be raised upward, while the power moves in a horizontal direction. The weight will also rise vertically through the same space that the rope is drawn horizontally. *Fig.* 81, represents two fixed pulleys, as they are arranged for such a purpose. In the erection of a lofty edifice, suppose the upper pulley to be suspended to some part of the building; then a horse pulling at the rope, A, would raise the weight, W, vertically, as far as he went horizontally.

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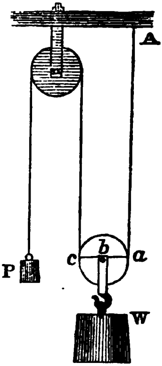
359. What is said of the application of this rule to complex machines? 360. What is a pulley? 361. What is a simple pulley? 362. What is a system of pulleys, or a compound pulley? 363. What is the most obvious advantage of the pulley? 364. How must two fixed pulleys be placed to raise a weight vertically as far as the power goes horizontally?

365. In the use of the *wheel* of the pulley, there is no mechanical advantage, except that which arises from removing the friction, and diminishing the imperfect flexibility of the rope.

In the mechanical effects of this machine, the result would be the same did it slide on a smooth surface with the same ease that its motion makes the wheel revolve.

366. The action of the pulley is on a different principle from that of the wheel and axle. A system of wheels, as already explained, acts on the same principle as the compound lever. But the mechanical efficacy of a system of pulleys is derived entirely from the division of the weight among the strings employed in suspending it.

FIG. 82.



Movable Pulley.

367. In the use of the single *fixed* pulley, there can be no mechanical advantage, since the weight rises as fast as the power descends. This is obvious by *Fig.* 80, where it is also apparent that the power and weight must be equal, to balance each other, as already shown.

In the single movable pulley, *Fig.* 82, the same rope passes from the fixed point, A, to the power, P. It is evident here, that the weight is supported equally by the two parts of the string between which it hangs. Therefore, if we call the weight, W, ten pounds, five pounds will be supported by one string, and five by the other. The power, then, will support twice its own weight; so that a person pulling with a force of five pounds at P, will raise ten pounds at W. The mechanical force, therefore, in respect to the power, is as two to one.

In this example, it is supposed there are only two ropes, each of which bears an equal part of the weight.

368. *Compound Pulley.*—If the number of ropes be increased, the weight may be increased with the same power; or the power may be diminished in proportion as the number of ropes is increased. In *Fig.* 83, the number of ropes sustaining the weight is four, and therefore, the weight may be four times as great as the power. This principle must be evident, since it

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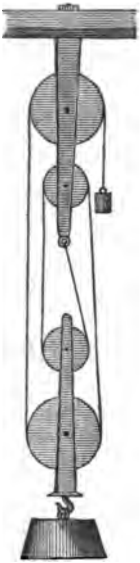
365. What is the advantage of the wheel of the pulley? 366. How does the action of the pulley differ from the wheel and axle? 367. Is there any mechanical advantage in the fixed pulley? What weight at P, Fig. 82, will balance ten pounds at W? 368. Suppose the number of ropes be increased, and the weight increased, must the power be increased also? Suppose the weight, Fig. 83, to be thirty-two pounds, what will each rope bear?

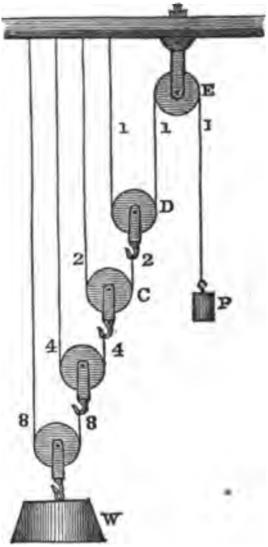
is plain that each rope sustains an equal part of the weight. The weight may, therefore, be considered as divided into four parts, and each part sustained by one rope.

FIG. 83.



Compound Pulley.

FIG. 84.



System of Pulleys.

369. In *Fig.* 84, there is a system of pulleys represented, in which the weight is sixteen times the power.

The tension of the rope, D E, is evidently equal to the power, P, because it sustains it. D, being a movable pulley, must sustain a weight equal to twice the power; but the weight which it sustains is the tension of the second rope, D C. Hence, the tension of the second rope is twice that of the first; and, in like manner, the tension of the third rope is twice that of the second, and so on, the weight being equal to twice the tension of the last rope.

370. Suppose the weight, W, to be sixteen pounds; then the two ropes, 8 and 8, would sustain 8 pounds each, this being the

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369. Explain Fig. 84, and show what part of the weight each rope sustains, and why one pound at P, will balance sixteen pounds at W. 370. Explain the reason why each additional rope and pulley will double the effect of the whole, or why its weight may be double that of all the others with the same power.

whole weight divided equally between them. The next two ropes, 4 and 4, would evidently sustain but half this whole weight, because the other half is already sustained by a rope fixed at its upper end. The next two ropes sustain but half of 4, for the same reason; and the next pair, 1 and 1, for the same reason, will sustain only half of 2. Lastly, the power, P, will balance two pounds, because it sustains but half this weight, the other half being sustained by the same rope, fixed at its upper end.

It is evident that, in this system, each rope and pulley which is added will double the effect of the whole. Thus, by adding another rope and pulley beyond 8, the weight, W, might be 32 pounds, instead of 16, and still be balanced by the same power.

371. In our calculations of the effects of pulleys, we have allowed nothing for the weight of the pulleys themselves, or for the friction of the ropes. In practice, however, it will be found that nearly one-third must be allowed for friction, and that the power, therefore, to actually raise the weight must be about one-third greater than has been allowed.

372. The pulley, like other machines, obeys the laws of virtual velocities, already applied to the lever and wheel. *Thus*, "*in a system of pulleys, the ascent of the weight or resistance is as much less than the descent of the power as the weight is greater than the power.*" If, as in the last example, the weight is 16 pounds, and the power 1 pound, the weight will rise only 1 foot, while the power descends 16 feet.

373. In the single fixed pulley, *Fig.* 80, the weight and power are equal; and, consequently, the weight rises as fast as the power descends.

With such a pulley, a man may raise himself up to the mast-head by his own weight. Suppose a rope is thrown over a pulley, and a man ties one end of it round his body, and takes the other end in his hands; he may raise himself up, because, by pulling with his hands, he has the power of throwing more of his weight on that side than on the other, and, when he does this, his body will rise. Thus, although the power and the weight are the same individual, still, the man can change his center of gravity so as to make the power greater than the weight, or the weight greater than the power, and thus can elevate one-half of his weight in succession.

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371. In compound machines, how much of the power must be allowed for the friction? **372.** What general law applies to the pulley? **373.** How may a man raise himself up by means of a rope and single fixed pulley?

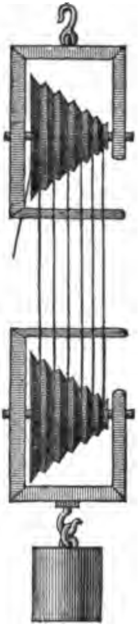
WHITE'S PULLEY.

374. In all the pulleys we have described, there is a great defect, in consequence of the different velocities at which the several wheels turn, and the consequent friction to which some of them are subjected.

375. It has been an object among mechanical philosophers to remedy this defect by inventing a system of pulleys, the wheels of which should all revolve on their axles in the same time, each making the same number of revolutions, notwithstanding the different lengths of rope passing over them, and thus avoid a defect common to those in use.

376. This object seems to have been fully attained by Mr. James White, whose invention is represented by *Fig.* 85, and which will be understood by the following description. In order that the successive wheels should revolve in the same time, and their circumferences should be just equal to the length of rope passing over them, Mr. White made them all of different diameters. By this construction, although the length of rope passing over each was different, yet, their revolutions are equal, both with respect to time and number.

FIG. 85.



White's Pulley.

By this arrangement, all the friction is avoided, except that of a pivot at each end, and the lateral friction of a single wheel. A single rope sustains the whole, and, as in other systems, the weight is as many times the power as there are ropes sustaining the lower block. This is considered the most perfect system of pulleys yet invented.

THE INCLINED PLANE.

377. *This power, the most simple of all machines, consists of a hard, smooth plane, inclined to the horizon in various degrees.*

It is the fourth mechanical power, and is represented by *Fig.* 86, where, from A to B, is the *inclined plane;* the line from D

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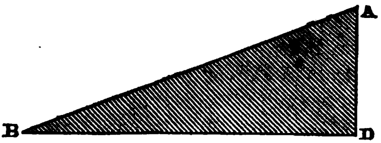
374. What is a great defect in the common pulley? 375. In what manner is it said that the defect with respect to friction might be remedied? 376. Describe White's pulley and show how the defects in other pulleys are remedied by this. 377. What is an inclined plane?

FIG. 86.



Inclined Plane.

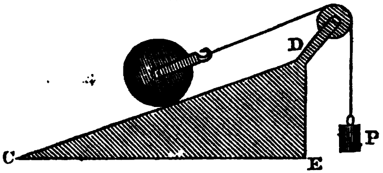
to A is its height, and that from B to D its base.

A board, with one end on the ground, and the other resting on a block, becomes an inclined plane.

378. This machine being both useful and easily constructed, is in very general use, especially (where heavy bodies are to be raised only to a small height.) Thus, a man, by means of an inclined plane, which he can readily construct (with a board or couple of bars,) can raise a load into his wagon, which ten men could not lift with their hands.

379. *The power required to force a given weight up an inclined plane (is in proportion to its height, and the length of its base ; or, in other words, the force must be (in proportion to the rapidity of its inclination)*

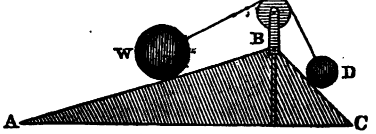
FIG. 87.



Inclined Plane.

380. The power, P, *Fig.* 87, pulling a weight up the inclined plane, from C to D, only raises it in an oblique direction from E to D, by acting along the whole length of the plane. If the plane be twice as long as it is high, that is, if the line from C to D be double the length of that from E to D, then one pound at P will balance two pounds any where between D and C. It is evident, by a glance at these figures, that, were the base lengthened, the height from E to D being the same, a less power at P would balance an equal weight any where on the inclined plane; and so, on the contrary, were the case made shorter, that is, the plane more steep, the power must be increased in proportion.

FIG. 88.



Inclined Plane.

381. Suppose two inclined planes, *Fig.* 88, of the same height, with bases of different lengths;

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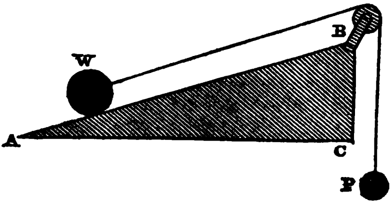
378. On what occasions is this power chiefly used? Suppose a man wants to put a barrel of cider into his wagon, how does he make an inclined plane for this purpose? 379. To roll a given weight up an inclined plane, to what must the force be proportioned? 380. Explain Fig. 87.

then the weight and power will be to each other as the length of the planes. If the length from A to B is two feet, and that from B to C one foot, then two pounds at D will balance four pounds at W, and so in this proportion, whether the planes be longer or shorter.

382. The same principle, with respect to the virtual velocities of the weight and power, applies to the inclined plane, in common with the other mechanical powers.

FIG. 89.



Inclined Plane.

Suppose the inclined plane, *Fig.* 89, to be two feet from A to B, and one foot from C to B; then, as we have already seen by *Fig.* 87, a power of one pound at P, would balance a weight of two pounds at W. Now, in the fall of the power to draw up the weight, it is obvious that its vertical descent must be just twice the vertical ascent of the weight; for, the power must fall down the distance from A to B, to draw the weight that distance; but, the vertical height to which the weight W is raised, is only from C to B. Thus, the power, being two pounds, must fall two feet to raise the weight, four pounds, one foot; and, thus, the power and weight, multiplied by their several velocities, are equal.

When the power of an inclined plane is considered as a machine, it must therefore be estimated by the proportion which, the length bears to the height; *the power being increased in proportion as the elevation of the plane is diminished.*

383. *Two forces of the inclined plane.* The weight of the carriage on the inclined plane, *Fig.* 90, may be resolved into two forces, namely, into B, C, which acts as a vertical pressure upon R, S, and B, A, which is directed downward parallel to R, S. Now, R, S, being the length, and, S, T, the height of the inclined plane, it can be proved by the laws of geometry from the similarity of the triangles, B, C, A, and R, S, T, that the downward propelling force, D, C, is in the proportion to the

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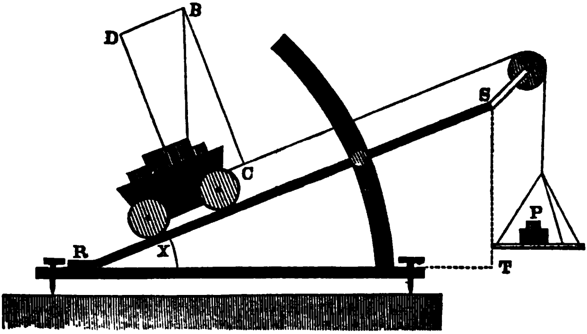
381. If the length of the long plane, Fig. 88, be double that of the short one, what must be the proportion between the power and the weight? 382. What is said of the application of the law of virtual velocities to the inclined plane? Explain Fig. 89, and show why the power must fall twice as far as the weight rises.

FIG. 90.



Inclined Plane.

weight of the body, D, C, as the height S, T, of the inclined plane, is to its length, R, T. If, therefore, the height, S, T, is the 4th, 5th, or 6th, of the length, R, T, then the force downwards will be equal to the 4th, 5th, or 6th, of the weight of the body, as shown by the balance weights, P.

384. APPLICATION TO ROADS.—Hilly roads may be regarded as inclined planes, and loads drawn upon them in carriages, considered in reference to the powers which draw them, are subject to all the conditions which we have stated, with respect to inclined planes.

The power required to draw a load up a hill, is in proportion to the elevation of the inclined plane. On a road perfectly horizontal, if the power is sufficient to overcome the friction, and the resistance of the atmosphere, the carriage will move. But if the road rises one foot in fifteen, besides these impediments, the moving power will have to lift one fifteenth part of the load.

385. Now, where is there a section of country in which the traveler is not vexed with roads, passing straight over hills, when precisely the same distance would carry him around them on a level plane? To use a homely, but very pertinent illustration, "the bale of a pot is no longer, when it lies down, than when it stands up." Had this simple fact been noticed, and its practical bearing carried into effect by road makers, many a high hill would have been shunned for a circuit around its base,

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384. How do the principles of the inclined plane apply to roads? 385. What is said about the bale of a pot, as applied to road making?

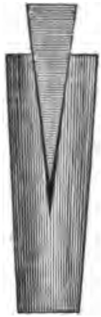
and many a poor horse, could he speak, would thank the wisdom of such a decision.

THE WEDGE.

386. *The next simple mechanical power is the wedge. This instrument may be considered as two inclined planes, placed base to base.*

It is much employed for the purpose of splitting or dividing solid bodies, such as wood and stone.

FIG. 91.



Wedge.

387. *Fig.* 91 represents such a wedge as is usually employed in cleaving timber. This instrument is also used in raising ships, and preparing them to launch, and for a variety of other purposes. Nails, awls, needles, and many cutting instruments, act, more or less, on the principle of this machine.

388. There is much difficulty in estimating the power of the wedge, since this depends on the force, or the number of blows given it, together with the obliquity of its sides. A wedge of great obliquity would require hard blows to drive it forward, for the same reason that a plane, much inclined, requires much force to roll a heavy body up it. But were the obliquity of the wedge, and the force of each blow given, still it would be difficult to ascertain the exact power of the wedge in ordinary cases, for, in the splitting of timber and stone, for instance, the divided parts act as levers, and thus greatly increase the power of the wedge. Thus, in a log of wood, six feet long, when split one half of its length, the other half is divided with ease, because the two parts act as levers, the lengths of which constantly increase, as the cleft extends from the wedge.

THE SCREW.

389. *The screw is the sixth and last simple mechanical power. It may be considered as a modification of the inclined plane, or as a winding wedge.*

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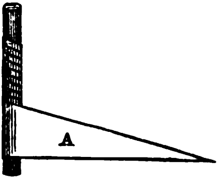
387. On what principle does the wedge act? In what case is this power useful? 387. What common instruments act on the principle of the wedge? 388. What difficulty is there in estimating the power of the wedge? 389. On what principle does the screw act?

FIG. 92.



Winding Wedge.

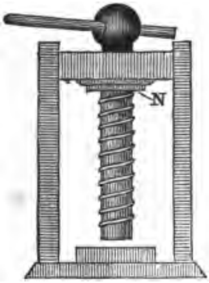
390. It is an inclined plane running spirally round a spindle, as will be seen by *Fig.* 92. Suppose A to be a piece of paper, cut into the form of an inclined plane and rolled round the piece of wood D; its edge would form the spiral line, called the *thread* of the screw. If the finger be placed between the two threads of a screw, and the screw be turned round once, the finger will be raised upward equal to the distance of the two threads apart. In this manner, the finger is raised up the inclined plane, as it runs round the cylinder.

The power of the screw is transmitted and employed by means of another screw called the *nut*, through which it passes. This has a spiral groove running through it, which exactly fits the thread of the screw.

If the nut is fixed, the screw itself, on turning it round, advances forward; but if the screw is fixed, the nut, when turned, advances along with the screw.

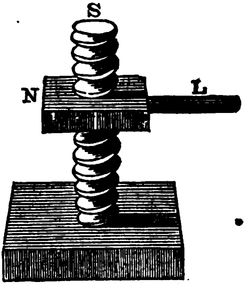
391. *Fig.* 93 represents the first kind of screw, being such as is commonly used in pressing paper, and other substances.

FIG. 93.



Nut Fixed.

FIG. 94.



Screw Fixed.

The nut, N, through which the screw passes, answers also for one of the beams of the press. If the screw be turned to the right, it will advance downward, while the nut stands still.

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390. How is it shown that the screw is a modification of the inclined plane? 391. Explain Fig. 93. Which is the screw, and which the nut? Which way must the screw be turned to make it advance through the nut?

392. A screw of the second kind is represented by *Fig.* 94. In this the screw is fixed, while the nut, N, by being turned by the lever, L, from right to left, will advance down the screw.

393. In practice, the screw is never used as a simple mechanical machine; the power being always applied by means of a lever, passing through the head of the screw, as in *Fig.* 93, or into the nut, as in *Fig.* 94.

394. POWER OF THE SCREW.—*The screw acts with the combined power of the inclined plane and the lever, and its force is such as to be limited only by the strength of the materials of which it is made.*

In investigating the effects of this machine, we must, therefore, take into account both these simple mechanical powers, so that the screw now becomes really a compound engine.

395. In the inclined plane, we have already seen, that the less it is inclined, the more easy is the ascent up it. In applying the same principle to the screw, it is obvious, that the greater the distance of the threads from each other, the more rapid the inclination, and consequently, the greater must be the power to turn it, under a given weight. On the contrary, if the thread inclines but slightly, it will turn with less power, for the same reason that a man can roll a heavy weight up a plane but little inclined. Therefore, the finer the screw, or the nearer the threads to each other, the greater will be the pressure under a given power.

396. Let us suppose two screws, the one having the threads one inch apart, and the other half an inch apart; then the force which the first screw will give with the same power at the lever, will be only half that given by the second. The second screw must be turned twice as many times round as the first, to go through the same space; but what is lost in velocity is gained in power. At the lever of the first, two men would raise a given weight to a given height, by making one revolution; while at the lever of the second, one man would raise the same weight to the same height, by making two revolutions.

397. It is apparent that the length of the inclined plane, up which a body moves in one revolution, is the circumference of the screw, and its height the interval between the threads. The proportion of its power would therefore be "*as the circum-*

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392. How does the screw, Fig. 93, differ from Fig. 94? 393. Is the screw ever used as a simple machine? By what simple power is it moved? 394. What two simple mechanical powers are concerned in the force of the screw? 395. Why does the nearness of the threads make a difference in the force of the screw? 396. Suppose one screw, with the threads one inch apart, and another half an inch apart, what will be their difference in force? 397. What is the length of the inclined plane, by which a body moves by one revolution of the screw?

ference of the screw, to the distance between the threads, so is the weight to the power.

398. By this rule the power of the screw alone can be found; but as this machine is moved by means of the lever, we must estimate its force by the combined power of both. In this case, the circumference described by the end of the lever employed, is taken, instead of the circumference of the screw itself. The means by which the force of the screw may be found, is therefore, by multiplying the circumference which the lever describes by the power.

399. Thus, "*the power multiplied by the circumference which it describes, is equal to the weight or resistance, multiplied by the distance between the two contiguous threads.*" Hence the efficacy of the screw may be increased, by increasing the length of the lever, or by diminishing the distance between the threads. If, then, we know the length of the lever, the distance between the threads, and the weight to be raised, we can readily calculate the power; or, the power being given, and the distance of the threads and the length of the lever known, we can estimate the weight the screw will raise.

400. Thus, suppose the length of the lever to be forty inches, the distance of the threads one inch, and the weight 8,000 pounds; required, the power, at the end of the lever, to raise the weight.

The lever being forty inches, the diameter of the circle, which the end describes, is 80 inches. The circumference is a little more than three times the diameter, but we will call it just three times. Then, 80 × 3 = 240 inches, the circumference of the circle. The distance of the threads is 1 inch, and the weight 8,000 pounds. To find the power, multiply the weight by the distance of the threads, and divide by the circumference of the circle. Thus,

Circum.		In.		Weight.		Power.
240	:	1	: :	8,000	:	33$\frac{1}{3}$

The power at the end of the lever must therefore be 33$\frac{1}{3}$ pounds. In practice, this power would require to be increased about one third, on account of friction.

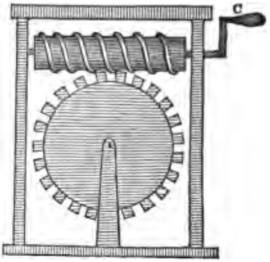
401. PERPETUAL SCREW.—*The force of the screw is sometimes employed to turn a wheel, by acting on its teeth. In this case it is called the perpetual screw.*

402. *Fig.* 95 represents such a machine. It is apparent,

399, How is the force of the screw estimated? How may the efficacy of the screw be increased? 400. The length of the lever, the distance between the threads, and the weight being known, how can the power be found? Give an example. 401. What is the screw called when it is employed to turn a wheel?

that by turning the crank C, the wheel will revolve, for the thread of the screw passes between the cogs of the wheel. By means of an axle, through the center of this wheel, like the common wheel and axle, this becomes an exceedingly powerful machine, but like all other contrivances for obtaining great power, its effective motion is exceedingly slow. It has, however, some disadvantages, and particularly the great friction between the thread of the screw and the teeth of the wheel, which prevents it from being generally employed to raise weights.

FIG. 95.



Screw and Wheel.

403. All these Mechanical Powers resolved into Three.—We have now enumerated and described all the mechanical powers usually denominated simple. They are six in number, namely, the Lever, Wheel and Axle, Pulley, Wedge, Inclined Plane, and Screw.

404. In respect to the principles on which they act, they may be resolved into (three simple powers, namely, the lever, the inclined plane, and the pulley;) for it has been shown that the wheel and axle is only another form of the lever, and that the screw is but a modification of the inclined plane.

It is surprising, indeed, that these simple powers can be so arranged and modified, as to produce the different actions in all that vast variety of intricate machinery which men have invented and constructed.

405. Card Machine.—The variety of motions we witness in the little engine which makes cards, by being supplied with wire for the teeth, and strips of leather to stick them through, would itself seem to involve more mechanical powers than those enumerated. This engine takes the wire from a reel; bends it into the form of teeth; cuts it off; makes two holes in the leather for the tooth to pass through; sticks it through; then gives it another bend on the opposite side of the leather; graduates the spaces between the rows of teeth, and between one tooth and another; and, at the same time, carries the leather backward and forward, before the point where the teeth are intro-

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402. Explain Fig. 95. What is the objection to this machine for raising weights? 403. How many simple mechanical powers are there, and what are they called? 404. How can they be resolved into three simple powers? 405. What is said of the card making machine?

duced, with a motion so exactly corresponding with the motions of the parts which make and stick the teeth, as not to produce the difference of a hair's breadth in the distance between them.

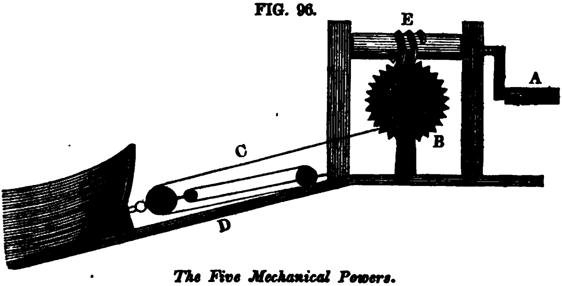
All this is done without the aid of human hands, any further than to put the leather in its place, and turn a crank; or, in some instances, many of these machines are turned at once, by means of three or four dogs, walking on an inclined plane which revolves.

406. Such a machine displays the wonderful ingenuity and perseverance of man; and, at first sight, would seem to set at naught the idea that the lever and wheel are the chief simple powers concerned in its motions. But, when these motions are examined singly and deliberately, we are soon convinced that the wheel variously modified, is the principal mechanical power in the whole engine.

407. Use of Machinery.—It has already been stated, (352,) that notwithstanding the vast deal of time and ingenuity which men have spent on the construction of machinery, and in attempting to multiply their powers, there has, as yet, been none produced, in which the power was not obtained at the expense of velocity, or velocity at the expense of power; and, therefore, no actual force is ever generated by machinery.

When men employ the natural elements as a power to overcome resistance by means of machinery, there is a vast saving of animal labor. Thus, mills, and all kinds of engines, which are kept in motion by the power of water, or wind, or steam, save animal labor equal to the power it takes to keep them in motion.

FIG. 96.



The Five Mechanical Powers.

408. *Five Mechanical Powers in one Machine.*—An engineer,

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406. What are the chief mechanical powers concerned in its motions? 407. Is there any actual force generated by machinery? What is said of employing the natural elements as a power? 408. What are the five mechanical powers employed in Fig. 96? Point out on the cut the place of each power.

it is said, for the purpose of drawing a ship out of the water to be repaired, combined the mechanical powers represented by *Fig.* 96, and perhaps no machine ever constructed gives greater force with so small a power.

(It involves the lever A, wheel and axle B, the pulley C, the inclined plane D, and the screw E.)

To estimate the force of this engine,(it is necessary to know the length of the lever, diameter of the wheel, &c.

Suppose then, the sizes of the different powers are as follows, viz.:—

Length of the lever A, ...	18 inches.
Distance of the thread E, ...	1 inch.
Diameter of the wheel B, ...	4 feet.
Diameter of the axle, ...	1 foot.
Pulleys C and D, D fixed, ...	4 strings.
Height of the plane D, one-half its length, .	2 feet.

Suppose the man turns the lever A, with the power equal to 100 pounds, the force on the ship would thus be found, for the different laws and rules referring to each mechanical power.

	Pounds.
1. One hundred pounds, on the lever A, would become a force, by means of the screw on the wheel B, of	11,309.76
2. Diameter of wheel four times that of the axle,	4
	45,239.04
3. The number of pulley-strings, ...	4
	180,956.16
4. Height of the inclined plane half its length, .	2
	361,912.32

The force on the ship, therefore,(would be equal to 361,912 pounds, or, about 161 tons.)

409. *Dick's Anti-Friction Press.*—Mr. Dick, the inventor of this press, resides at Meadsville, Pa.

The principle of this most powerful engine is so obvious, on inspecting the diagram, *Fig.* 97, that no description of it would be required by a practical mechanic. We, however, subjoin the following, in order to make it plain to the student.

The center wheel, B, has two eccentrics or cams, A A, making parts of B, and cast with it. The two sectors, C C,

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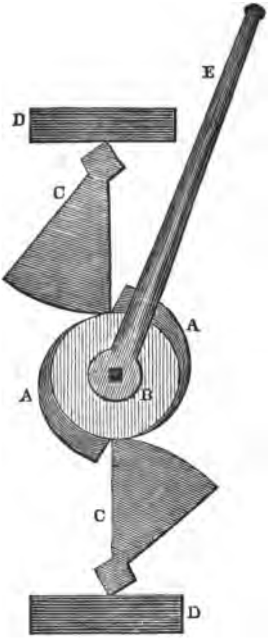
408. What must be known to estimate the power of this machine? What is the amount of force on the ship? 409. Describe Dick's Anti-Friction Press, and give some account of its power

FIG. 97.



Dick's Press.

are angular, or wedge-shaped, where they bear on the followers or impediments, D D.

Action. — On moving the lever, E, to the right or downwards, the sectors move with the eccentrics or inclined planes by the traction between the two faces of iron, and thus, D D will be moved from each other to a distance equal to the sum of the inclined planes, A A. If each of the eccentrics are twelve inches, then D D will be moved asunder two feet, and so, in this proportion, more or less. As the center wheel has no bearings or support except the sectors, C C, there can be no friction except where these touch the followers, D D; and, as these points of motion are sharp edges, no appreciable friction appears to exist in the action of this most simple machine.

410. *Application and Power of Dick's Press.*—The following is abridged from the New York Sun. The piles, on which the force was applied, were at the Navy Yard, in Brooklyn, N. Y. They were 50 feet long, 15 inches square, and driven 40 feet into the ground, doweled and spiked and crowded together by wedges, driven between them by the pile-driver. To extract one of these piles was the great object, since, this being done, the others could be removed with comparative ease. For this purpose, an experiment was made with a lever of wood, 30 feet long, and 22 by 18 inches in diameter. The fulcrum was eighteen inches from the end, and to the long arm was attached a six-fall tackle, the rope being attached to a capstan, worked by six men, the levers being of the usual length. This immense force was applied to one of the piles, but the grappling broke, without starting it in the least. A few days after, proper fixtures being made, Dick's anti-friction press, constructed of uncommon size for the purpose, was applied to the work. This

was a new machine, and, as its name imports, works with the perfect annihilation of all friction. Curiosity was on tiptoe, and the officers of the navy and army, engineers, and many citizens were present to witness the effect. The machine was secured to the pile with heavy iron bars, and a three-inch iron bolt passing through both. Breathless silence prevailed throughout the crowd, and the most intense excitement was felt by all immediately concerned, while four men only, took hold of the lever in order to make the tremendous lift; for, all thought, after the experiment with the 30-foot lever, that nothing could be done by so diminutive a machine. The first strain started the pile three-quarters of an inch, when the iron bolt was broken, but a shout gave notice that the force had succeeded. The next day, the force was again applied, with complete success; and, such was the tremendous power the machine exerted, that, instead of one pile, three or four were started, the whole series being trunneled together. Thus was this little engine triumphant, and the agony over.

X CHAPTER V.

HYDROSTATICS.

411. *Hydrostatics is the science which treats of the weight, pressure, and equilibrium of water, or other fluids, when in a state of rest.*

412. *Hydraulics* is that part of the science of fluids which treats of water in motion, and the means of raising and conducting it in pipes, or otherwise, for all sorts of purposes.

The subject of water at rest will first claim investigation, since the laws which regulate its motion will be best understood by first comprehending those which regulate its pressure.

413. DEFINITION.—*A fluid is a substance whose particles are easily moved among each other, as air and water.*

414. The air is called an *elastic* fluid, because it is easily compressed into a smaller bulk, and returns again to its original state when the pressure is removed. Water is called a *non-*elastic fluid, because it admits of little diminution of bulk under pressure.

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411. What is hydrostatics? 412. How does hydraulics differ from hydrostatics? 413. What is a fluid? 414. What is an elastic fluid? Why is air called an elastic fluid

415. The non-elastic fluids are perhaps more properly called *liquids*, but both terms are employed to signify water and other bodies possessing its mechanical properties. The term *fluid*, when applied to the air, has the word *elastic* before it.

416. One of the most obvious properties of fluids is the facility with which they yield to the impressions of other bodies, and the rapidity with which they recover their former state, when the pressure is removed. The cause of this is the freedom with which their particles slide over, or among each other; their cohesive attraction being so slight as to be overcome by the least impression. On this want of cohesion among their particles seems to depend the peculiar mechanical properties of these bodies.

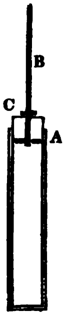
417. In solids, there is such a connection between the particles, that, if one part moves, the other part must move also. But, in fluids, one portion of the mass may be in motion, while the other is at rest. In solids, the pressure is always downward or toward the center of the earth's gravity; but, in fluids, the particles seem to act on each other as wedges, and hence, when confined, the pressure is sideways, and even upward, as well as downward.

418. *Elasticity of Water.*—Water has commonly been called a non-elastic substance; but, it is found that, under great pressure, its volume is slightly diminished, and hence it is proved to be elastic. The most decisive experiments on this subject were made, many years ago, by Mr. Perkins.

419. These experiments were made by means of a hollow cylinder, *Fig.* 98, which was closed at the bottom, and made water-tight at the top, by a cap screwed on. Through this cap, at A, passed the rod B, which was five-sixteenths of an inch in diameter. The rod was so nicely fitted to the cap, as also to be water tight. Around the rod, at C, there was placed a flexible ring, which could be easily pushed up or down, but fitted so closely as to remain on any part where it was placed.

A cannon of sufficient size to receive this cylinder, which was three inches in diameter, was furnished with a strong cap and forcing pump, and set vertically into the ground. The cannon and cylinder

FIG. 98.



Water Elastic.

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415. What substances are called liquids? 416. What is one of the most obvious properties of liquids? 417. On what do the peculiar mechanical properties of fluids depend? In what respect does the pressure of a fluid differ from that of a solid? 418. Is water an elastic, or a non-elastic fluid? 419. Describe Fig. 98, and show how water was found to be elastic.

were next filled with water, and the cylinder, with its rod drawn out, and the ring placed down to the cap, as in the figure, was plunged into the cannon. The water in the cannon was then subjected to an immense pressure by means of the forcing pump, after which, on examination of the apparatus, it was found that the ring, C, instead of being where it was placed, was eight inches up the rod. The water in the cylinder being compressed into a smaller space by the pressure of that in the cannon, the rod was driven in, while under pressure, but was forced out again by the expansion of the water, when the pressure was removed. Thus, the ring on the rod would indicate the distance to which it had been forced in during the greatest pressure.

420. This experiment proved that water, under the pressure of one thousand atmospheres, that is the weight of 15,000 pounds to the square inch, was reduced in bulk about one part in 24.

So slight a degree of elasticity, under such immense pressure, is not appreciable under ordinary circumstances, and, therefore, in practice, or in common experiments on this fluid, water is considered as non-elastic.

EQUAL PRESSURE OF WATER.

421. *The particles of water, and other fluids, when confined, press on the vessel which confines them, in all directions, both upward, downward, and sideways.*

From this property of fluids, together with their weight, very unexpected and surprising effects are produced.

The effect of this property, which we shall first examine, is, that a quantity of water, however small, will balance another quantity, however large. Such a proposition, at first thought, might seem very improbable. But, on examination, we shall find that an experiment with a very simple apparatus will convince any one of its truth. Indeed, we every day see this principle established by actual experiment, as will be seen directly.

422. This principle is strikingly illustrated by *Fig.* 99. Suppose the cistern A to be capable of holding one hundred gallons, and into its bottom there be fitted the tube B, bent, as seen in the figure, and capable of containing one gallon. The top of the cistern, and that of the tube, being open, pour water into the tube at C, and it will rise up through the perpen-

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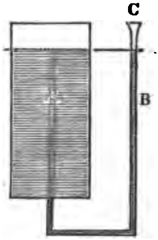
420. In what proportion does the bulk of water diminish under a pressure of 15,000 pounds to the square inch? In common experiments, is water considered elastic or non-elastic? **421.** When water is confined, in what direction does it press? **422.** Explain Fig. 99, and show how the pressure in the tube is equal to the pressure in the cistern.

FIG. 99.



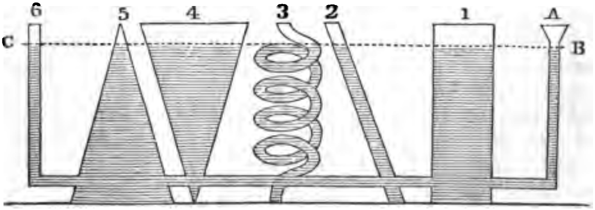
Pressure of Water.

dicular bend into the cistern, and if the process be continued, the cistern, will be filled by pouring water into the tube. Now it is plain, that the gallon of water in the tube presses against the hundred gallons in the cistern, with a force equal to the pressure of one hundred gallons, otherwise, that in the tube would be forced upward higher than that in the cistern, whereas, we find that the surfaces of both stand exactly at the same height.

423. From this experiment we learn, "*that the pressure of a fluid is not in proportion to its quantity, but to its height, and that a large quantity of water in an open vessel, presses with no more force than a small quantity of the same height.*"

424. *Pressure equal in Vessels of all Sizes and Shapes.*—The size or shape of a vessel is of no consequence, for if a number of vessels differing entirely from each other in figure, position, and capacity, have a communication made between them, and one be filled with water, the surface of the fluid, in all, will be at the same elevation. If, therefore, the water stands at an equal height in all, the pressure in one must be just equal to that in another, and so equal to that in all the others.

FIG. 100.



Equal Pressure of Water.

425. To make this obvious, suppose a number of vessels, of different shapes and sizes, as represented by *Fig.* 100, to have a communication between them, by means of a small tube,

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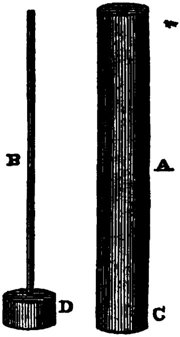
423. What conclusion, or general truth, is to be drawn from this experiment? 424. What difference does the shape or size of a vessel make in respect to the pressure of a fluid on its bottom? 425. Explain Fig. 100, and show how the equilibrium is produced.

passing from the one to the other. If, now, one of these vessels be filled with water, or if water be poured into the tube A, all the other vessels will be filled at the same instant, up to the line B C. Therefore, the pressure of the water in A, balances that in 1, 2, 3, &c., while the pressure in each of these vessels is equal to that in the other, and so an equilibrium is produced throughout the whole series.

426. If an ounce of water be poured into the tube A, it will produce a pressure on the contents of all the other vessels, equal to the pressure of all the others on the tube: for, it will force the water in all the other vessels to rise upward to an equal height to that in the tube itself. Hence, we must conclude, that the pressure in each vessel is not only equal to that in any of the others, but also that the pressure in any one is equal to that in all the others.

427. *Pressure as the height and area of the base.* By other experiments, it is ascertained, ***that the pressure of a liquid is in proportion to its height, and the area of its base.***

FIG. 101.



428. Suppose a vessel, ten feet high, and two feet in diameter, such as is represented at A, *Fig.* 101, to be filled with water; there would be a certain amount of pressure, at C, near the bottom. Let D represent another vessel, of the same diameter at the bottom, but only a foot high, and closed at the top. Now if a small tube, the fourth of an inch in diameter, be inserted into the cover of this vessel, and the tube be carried to the height of the vessel A, and then the vessel and tube be filled with water, the pressure on the bottoms and sides of both vessels at the same height will be equal, and jets of water starting from D and C will have exactly the same force, and spout to the same distance.

This might at first seem improbable, but to convince ourselves of its truth, we have only to consider, that any impression made on one portion of the confined fluid in the vessel D, is instantly communicated to the whole mass. Therefore, the water in the tube B, presses with the same force on every other portion of

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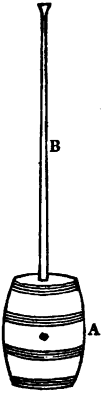
426. Suppose an ounce of water be poured into the tube A, what will be its effect on the contents of the other vessels? 428. How is a small quantity of water shown to press equal to a large quantity by Fig. 101?

the water in D, as it does on that small portion over which it stands. (See *Fig.* 100, 424.)

429. *Bursting a Cask.*—This principle is illustrated in a very striking manner, by the experiment, which has often been made, of bursting a common wine cask with a few ounces of water. This experiment requires that the cask should contain 50 or 60 gallons. A small keg will not burst, unless the tube be 100 feet high.

FIG. 102.



Bursting a Cask.

Suppose A, *Fig.* 102, to be such a cask, already filled with water, and suppose the tube B, fifty feet high, to be screwed, water-tight, into its head. When water is poured into the tube, so as to fill it gradually, the cask will show increasing signs of pressure, by emitting the water through the pores of the wood, and between the joints; and, finally, as the tube is filled, the cask will burst asunder.

430. *Jet of Water.*—The same apparatus will serve to illustrate the upward pressure of water; for, if a small stop-cock be fitted to the upper head, on turning this, when the tube is filled, a jet of water will spirt up with a force, and to a height, that will astonish all who never before saw such an experiment.

In theory, the water will spout to the same height with that which gives the pressure, but, in practice, it is found to fall short in the following proportions:—

431. If the tube be twenty feet high, and the orifice for the jet half an inch in diameter, the water will spout nearly nineteen feet. If the tube be fifty feet high, the jet will rise upward of forty feet, and if a hundred feet, it will rise above eighty feet. It is understood, in every case, that the tubes are to be kept full of water.

The height of these jets shows the astonishing effects that a small quantity of fluid produces when pressing from a perpendicular elevation.

432. HYDROSTATIC PARADOX.—This paradox, illustrated by

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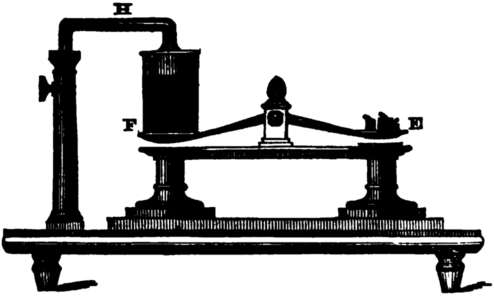
429. Explain the reason why the pressure is as great at D, as at C. How is the same principle illustrated by Fig. 102? **430.** How may Fig. 102 be made to illustrate the upward pressure of water? **431.** Under the pressure of a column of water twenty feet high, what will be the height of the jet? Under a pressure of a hundred feet, how high will it rise?

FIG. 103.



Hydrostatic Paradox.

Fig. 103, consists in experimental proof of the principle already insisted on, that water presses according to its height, and not to its quantity. Fill a glass jar with water, and balance it on the scale-beam F, E, with small weights. Then pour out the water, leaving only an inch or two deep, letting the balance weights remain. Replacing the jar, which will now stand higher than before, owing to the loss of water, introduce into it, by means of the crane, H, a piece of wood a few lines smaller in all directions than the inside of the jar. The wood being adjusted by means of the thumb-screw, so that the water is made to rise around it exactly to the brim, or as high as it stood before any was poured out, (the wood not touching the glass,) and it will be found that it will exactly balance the weights, as it did when full of water, though it now contains only a tenth as much as before.

The result will be the same if, instead of the wood, the same bulk of cork or lead be placed in the jar, the only point being, that, in each case, the water should rise to the same height.

The above experiment proves, in a very striking manner, that the pressure of water is as its height; and the reason why it makes no difference in the result whether the body placed in the jar be of wood, cork, or lead is, that the solid merely takes the place of the fluid, displacing its own bulk, and thus the weight remains just as though the water itself had remained in the jar. Thus, the pressure of a tenth part of the water, of equal height, equals the whole.

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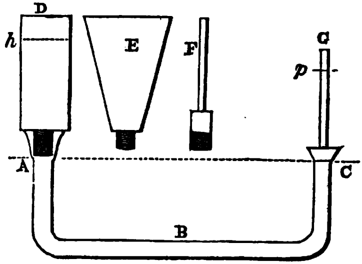
432. What does the hydrostatic paradox show? Explain by the figure how the experiment is made

433. *Proof by Mercury.*—In addition to the above proofs, that a small will balance a large quantity of water, we add the following perhaps the most satisfactory of all.

Let A, B, C. *Fig.* 104, represent a glass tube, having at A, a collar cemented to the glass, into which vessels of different capacities and shapes, may be screwed. The tube is first filled with mercury up to the level of the dotted line A C, and the tube G *p*, fitted in its place. The vessel D, is then screwed into A, and water is poured in as far as *h*, the base of the column of water being, as seen, equal to that of the mercury. The fluid metal will rise, by the pressure of the water on A, up to *p* in the small tube. Then unscrew D, and in its place fix the conical vessel E, and pour in water as before, and the same result will follow, and so with the small tube F; in each case, the height of the of the water, notwithstanding the difference in quantity, will force the mercury to exactly the same elevation.

FIG. 104.

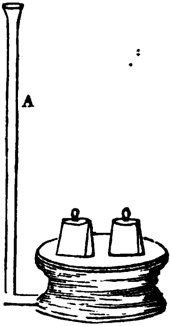


Proof by Mercury.

434. Hydrostatic Bellows.—An instrument called the hydrostatic bellows, also shows, in a striking manner, the great force of a small quantity of water, pressing in a perpendicular direction.

This instrument consists of two boards, connected together with strong leather, in the manner of the common bellows. It is then furnished with a tube A, *Fig.* 105, which communicates between the two boards. A person standing on the upper board may raise himself up by pouring water into the tube.

FIG. 105.



Hydrostatic Bellows.

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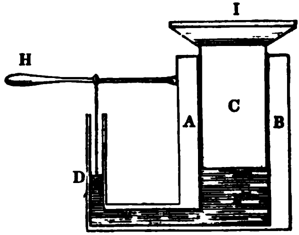
433. Explain Fig. 104, and show in what manner different quantities of water will balance the same weight of mercury, 434. What is the hydrostatic bellows? What property of water is this instrument designed to show?

It the tube holds an ounce of water, and has an area equal to a thousandth part of the area of the top of the bellows, one ounce of water in the tube will balance a thousand ounces placed on the bellows.

435. Hydrostatic Press.—This property of water was applied by Mr. Bramah, to the construction of his *hydrostatic* press. But instead of a high tube of water, which in most cases could not be so readily obtained, he substituted a strong forcing-pump, and instead of the leather bellows, a metallic pump, barrel, and piston.

436. This arrangement will be understood by *Fig.* 106, where the pump-barrel, A, B, is represented as divided lengthwise, in order to show the inside. The piston, C, is fitted so accurately to the barrel, as to work up and down water-tight; both barrel and piston being made of iron. The thing to be broken or pressed, is laid on the flat surface, I, there being above this, a strong frame to meet the pressure, not shown in the figure. The small forcing pump, of which D is the piston, and H, the lever by which it is worked, is also made of iron.

FIG. 106.



Hydrostatic Press.

Now suppose the space between the small piston and the large one, at W, to be filled with water, then on forcing down the small piston, D, there will be a pressure against the large piston, C, the whole force of which will be in proportion as the aperture in which C works, is greater than that in which D works.

437. Use of the Hydrostatic Press.—Having explained by *Fig.* 106. the principle on which this press acts, we here, *Fig.* 107, show one of the many uses to which it is applied, viz: the pressure of books before they are bound. The lever, B, works the small forcing pump, D, which is supplied with water from the tank, into which it dips. A tube from this admits the fluid into the cylinder (not shown) under the large piston, which rises with a force in proportion to the sizes of the two pistons, as above explained. The top of the press and the

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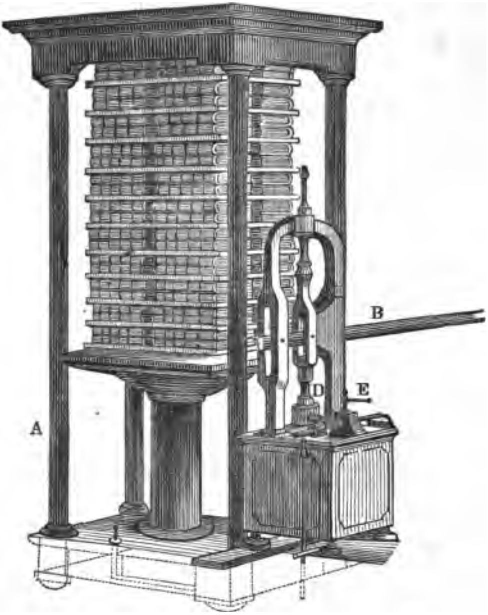
435. Explain Fig. 106. Where is the piston? Which is the pump-barrel in which it works? Explain Fig. 107.

FIG. 107.



Use of the Press.

pillars, A, are of iron, the latter of wrought metal. When the pressure is sufficient, the stop-cock, E, is turned, and the piston remains at rest as long as the case requires. On the top of the small tank there is a lever connected with the safety valve. Instead of water, whale oil is used in these presses, because it neither freezes nor evaporates.

438. *Estimated Force.*—It is evident that the force to be obtained by this principle, can only be limited by the strength of the materials of which the engine is made. Thus, if a pressure of two tons be given to a piston, the diameter of which is only a quarter of an inch, the force transmitted to the other piston, if three feet in diameter, would be upward of 40,000 tons; but such a force is much too great for the strength of any material with which we are acquainted.

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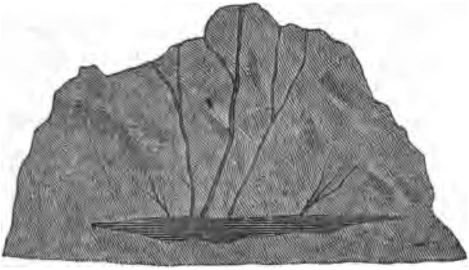
438. If the pressure of two tons be made on a piston of a quarter of an inch in diameter, what will be the force transmitted to the other piston of three feet in diameter?

A small quantity of water, extending to a great elevation, would give the pressure above described, it being only for the sake of convenience, that the forcing-pump is employed instead of a column of water.

439. *Rupture of a Mountain.*—There is no doubt, but in the operations of nature, great effects are sometimes produced among mountains, by a small quantity of water finding its way to a reservoir in the crevices of the rocks far beneath.

FIG. 108.



Rupture of a Mountain.

Suppose, in the interior of a mountain, *Fig.* 108, there should be a space of ten yards square, and an inch deep, filled with water, and closed up on all sides; and suppose that, in the course of time, a small fissure, no more than an inch in diameter, should be opened by the water, from the height of two hundred feet above, down to this little reservoir. The consequence might be, that the side of the mountain would burst asunder, for the pressure, under the circumstances supposed, would be equal to the weight of five thousand tons.

440. *Pressure on Vessels with Oblique Sides.*—It is obvious, that, in a vessel, the sides of which are every where perpendicular to each other, the pressure on the bottom will be as the height, and that the pressure on the sides will every where be equal, at an equal depth of the liquid.

But it is not so obvious, that in a vessel having oblique sides, that is, diverging outward from the bottom, or converging from the bottom toward the top, in what manner the pressure will be sustained.

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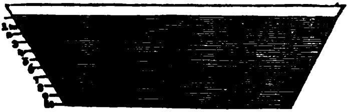
439. What is said of the pressure of water in the crevices of mountains and its effects? 440. What is the pressure on the bottom of a vessel containing a fluid equal to? Suppose the sides of the vessel slope outward, what effect does this produce on the pressure?

441. Now, the pressure on the bottom of any vessel, no matter what the shape may be, is equal to the height of the fluid, and the area of the bottom, (428.)

FIG. 109.



Pressure on Diverging Sides.

Hence the pressure on the bottom of the vessel sloping outward, *Fig.* 109, will be just equal to what it would be, were the sides perpendicular, and the same would be the case did the sides slope inward instead of outward. In a vessel of this shape, the sides sustain a pressure equal to the perpendicular height of the fluid, above any given point.

PRESSURE OF WATER IN POUNDS, AT VARIOUS DEPTHS.

442. The weight of a cubic inch of water at the temperature of 62°, is the 0.036065 fraction of a pound. A column of water one foot high, being twelve times the above, would therefore be 0.4328 pounds.

443. Now a square foot is 144 square inches, and therefore the pressure, or weight, of a square foot of water will be found by multiplying the above fraction by 144, which gives 62.3232, or nearly 62 and a third pounds. Omitting the decimals, a cubic foot of water is commonly estimated at 62 pounds.

The following table, founded on the above estimates, may be useful in determining the pressure of water in pipes or other vessels, of known depth.

Depth in Feet.	Pressure per square Inch.	Pressure per square Foot.
	Pounds.	Pounds.
1......	......0.4328......	..... 62.3232
2......	......0.8656......	.....124.6464
3......	......1.2984......	.....186.9696
4......	......1.7312......	.....249.2928
5......	......2.1640......	.....311.6160
6......	......2.5968......	.....373.9392
7......	......3.0296......	.....436.2624
8......	......3.4624......	.....498.5856
9......	......3.8952......	.....560.9088
10......	......4.3280......	.....623.2320

Suppose it is required to know the pressure on the bottom

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441. On the contrary, did the sides of the vessel slope inward exactly the same amount of pressure according to the height, what would be the result? 442. What is the weight of a cubic inch of water? What is the weight of a cubic foot of water?

of a vessel of water, 1 foot square and 20 feet deep, then it is found by doubling that of 10 feet deep, thus 623.2320 × 2 = 1246.464 pounds. The pressure on a tube equal to an inch square, and of an equal depth, is found by substituting inches for feet as above seen.

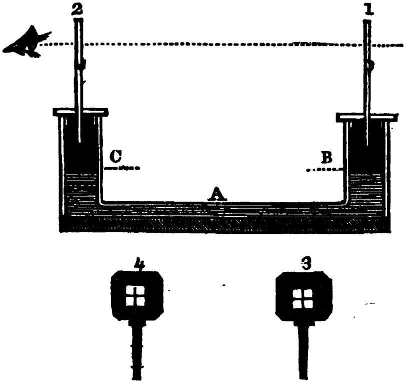
WATER LEVEL.

444. We have seen, that in whatever situation water is placed, it always tends to seek a *level.* (424.) Thus, if several vessels communicating with each other be filled with water, the fluid will be at the same height in all, and the level will be indicated by a straight line drawn through all the vessels as in *Fig.* 100.

It is on the principle of this tendency that the little instrument called the *water level* is constructed.

445. Let A, *Fig.* 110, be a straight glass tube having two legs, or two other glass tubes rising from each end at right-angles. Let the tube A, and a part of the legs, be filled with mercury or some other liquid, and on the surfaces, B C, of the liquid, let floats be placed, carrying upright wires, to the ends of which are attached sights at 1, 2. These sights are represented by 3, 4, and consist of two fine threads or hairs, stretched at right-angles across a square, and are placed at right-angles to the length of the instrument.

FIG. 110.



Improved Water Level.

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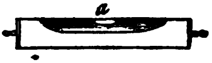
445. Explain by Fig. 110, how an exact line may be obtained by adjusting the sights.

446. They are so adjusted that the point where the hairs intersect each other, shall be at equal heights above the floats. The principles on which this adjustment depends are easily explained, and is as follows: if the intersections of the hairs be at the same distance from the floats, the line joining these intersections will evidently be parallel to the lines joining the surfaces B, C, of the liquid, and will therefore be level. But if one of these points be more distant from the floats than the other, the line joining the intersections will point upward if viewed from the lower sight, and downward if viewed from the higher one.

The accuracy of the results of this instrument, will be greatly increased by lengthening the tube A.

FIG. 111.



Spirit Level.

447. *Spirit Level.*—The common *spirit level* consists of a glass tube, *Fig.* 111, filled with spirit of wine, excepting a small space in which there is left a bubble of air. This bubble, when the instrument is laid on a level surface, will be exactly in the middle of the tube, and therefore, to adjust a level, it is only necessary to bring the bubble to this position.

The glass tube is inclosed in a brass case, which is cut out on the upper side, so that the bubble may be seen, as represented in the figure.

448. This instrument is employed by builders to level their work, and is highly convenient for that purpose, since it is only necessary to lay it on a beam to try its level.

SPECIFIC GRAVITY.

449. *If a tumbler be filled with water to the brim, and an egg, or any other heavy solid, be dropped into it, a quantity of the fluid, exactly equal to the size of the egg, or other solid, will be displaced, and will flow over the side of the vessel.* Bodies which sink in water, therefore, displace a quantity of the fluid equal to their own bulks.

450. Now, it is found by experiment, that when any solid substance sinks in water, it loses, while in the fluid, a portion of its weight, just equal to that of the bulk of water which it displaces. This is readily made evident by experiment.

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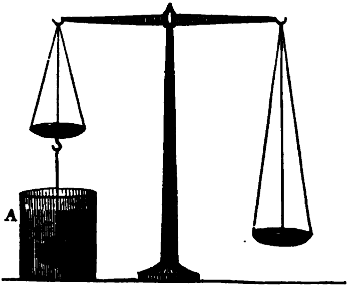
446. Explain the principle on which the water level with sights is constructed. 447. Describe the common spirit level, and the method of using it. 448. What is the use of the level? 449. How much water will an egg displace? 450. How much less will a cubic inch of any substance weigh in water than in air?

451. Take a piece of ivory, or any other substance that will sink in water, and weigh it accurately in the usual manner; then suspend it by a thread, or hair, in the empty cup A, *Fig.* 112, and balance it, as shown in the figure. Now pour water into the cup, and it will be found that the suspended body will lose a part of its weight, so that a certain number of grains must be taken from the opposite scale, in order to make the scales balance as before the water was poured in. The number of grains taken from the opposite scale, show the weight of a quantity of water equal to the bulk of the body so suspended.

FIG. 112.



Weighing in Water.

452. It is on this principle, that bodies weigh less in the water than they do when weighed out of it, or in the air, that water becomes the means of ascertaining their specific gravities, for it is by comparing the weight of a body *in* the water, with what it weighs *out* of it, that its specific gravity is determined.

Thus, suppose a cubic inch of gold weighs 19 ounces, and on being weighed in water, weighs only 18 ounces, or loses a nineteenth part of its weight, it will prove that gold, bulk for bulk, is nineteen times heavier than water, and thus 19 would be the specific gravity of gold. And so if a cube of copper weigh 9 ounces in the air, and only 8 ounces in the water, then copper, bulk for bulk, is 9 times as heavy as water, and therefore has a specific gravity of 9.

453. If the body weighs less, bulk for bulk, than water, it is obvious that it will not sink in it, and therefore weights must be added to the lighter body, to ascertain how much less it weighs than water.

The specific gravity of a body, then, is merely its weight compared with the same bulk of water; and water is thus made the standard by which the weights of all other bodies are compared.

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451. How is it proved by Fig. 112, that a body weighs less in water than in air? 452. On what principle are specific gravities found? 453. What is the specific gravity of a body?

454. *How to take the Specific Gravity.*—To take the specific gravity of a solid which sinks in water, first weigh the body in the usual manner, and note down the number of grains it weighs; then, with a hair, or fine thread, suspend it from the bottom of the scale-dish, in a vessel of water, as represented by *Fig.* 112. As it weighs less in water, weights must be added to the side of the scale where the body is suspended, until they exactly balance each other. Next, note down the number of grains so added, and they will show the difference between the weight of the body in air and in water.

455. It is obvious that the greater the specific gravity of the body, the less, comparatively, will be this difference, because each body displaces only its own bulk of water, and some bodies of the same bulk will weigh many times more than others.

456. For example, suppose that a piece of platina, weighing 22 ounces, will displace an ounce of water, while a piece of silver, weighing 22 ounces, will displace two ounces of water. The platina, therefore, when suspended as above described, will require one ounce to make the scales balance, while the same weight of silver will require two ounces for the same pnrpose. The platina, therefore, bulk for bulk, will weigh twice as much as the silver, and will have twice as much specific gravity.

Having noted down the difference between the weight of the body in air and in water, as above explained, the specific gravity is found by dividing the weight in air by the loss in water. The greater the loss, therefore, the less will be the specific gravity, the bulk being the same.

457. Thus, in the above example, 22 ounces of platina was supposed to lose one ounce in water, while 22 ounces of silver lost two ounces in water. Now, 22 divided by 2, the loss of the platina, is 11; and 22 divided by 2, the loss in the silver, is 11. So that the specific gravity of platina is 11, while that of silver is 22. The specific gravities of these metals are, however, a little less than here estimated.

458. TABLE OF SPECIFIC GRAVITIES.

SUBSTANCES.	Sp. Gr.	SUBSTANCES.	Sp. Gr.	SUBSTANCES.	Sp. Gr.
Cork,..............	0,24	Milk,..............	1,030	Chromium,.........	5,900
Poplar Wood,......	0,38	Oak Wood,........	1,170	Antimony,.........	6,712
Lime Tree,.........	0,439	Phosphorus,.........	1,770	Zinc,..............	7,037
Nut Wood,.........	0,677	Sulph. Acid,......	1,846	Iron, (wrought)....	7,788
Ether,..............	0,713	Ivory,.............	1,917	Steel,..............	8,816
Pine Wood,........	0,555	Sulphur,...........	2,03	Copper, (wrought).	8,875
Alcohol,...........	0,793	Quartz,............	2,6	Bismuth,..........	9,820
Oil Turpentine,....	0,872	Basalt,............	2,66	Silver,............	10,474
Poppy Oil..........	0,929	Bottle Glass,.......	2,60	Lead,..............	11,852
Ice,................	0,916	Granite,...........	2,80	Mercury,..........	13,598
Water,............	1,000	Diamond,..........	3,52	Gold,..............	19,325
Sea Water,........	1,026	Heavy Spar,.......	4,426	Platinum,..........	22,100

Remarks.—The wood in the above is supposed to be dry, and the Alcohol or Turpentine to be of the usual strength.

HYDROMETER.

This term comes from two Greek words, meaning water and to measure, that is to measure the weight of water.

459. *The hydrometer is an instrument by which the specific gravities of fluids are ascertained by the depth to which the instrument sinks below their surfaces.*

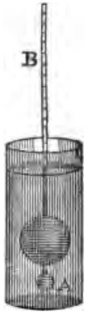
460. Suppose a cubic inch of lead loses, when weighed in water, 253 grains, and, when weighed in alcohol, only 209 grains, then, according to the principle already recited, a cubic inch of water actually weighs 253, and a cubic inch of alcohol 209 grains, for when a body is weighed in a fluid, it loses just the weight of the fluid it displaces.

461. Water, as we have already seen, (453,) is the standard by which the weights of other bodies are compared, and by ascertaining what a given bulk of any substance weighs in water, and then what it weighs in any other fluid, the comparative weight of water and this fluid will be known. For if, as in the above example, a certain bulk of water weighs 253 grains, and the same bulk of alcohol only 209 grains, then alcohol has a specific gravity nearly one fourth less than water.

462. It is on this principle that the hydrometer is constructed. It is composed of a hollow ball of glass, or metal, with a graduated scale rising from its upper part, and a weight on its under part, which serves to balance it in the fluid.

Such an instrument is represented by *Fig.* 113, of which B, is the graduated scale, and A, the weight, the hollow ball being between them.

FIG, 113.



Hydrometer.

463. To prepare this instrument for use, weights in grains, or half-grains, are put into the little cup, A, until the scale is carried down so that a certain mark on it coincides exactly with the surface of the water. This mark, then, becomes the standard of comparison between water and any other liquid in which the hydrometer is placed.

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454. How are the specific gravities of solid bodies taken? 455. Why does a heavy body weigh comparatively less in the water than a light one? 456. Having taken the difference between the weight of a body in air and in water, by what rule is the specific gravity found? 457. Give the example stated, and show how the difference between the specific gravities of platina and silver is found. 459. What is the Hydrometer? 460. Suppose a cubic inch of any substance weighs 253 grains less in water than in air, what is the actual weight of a cubic inch of water? 461. On what principle is the hydrometer founded? 462. How is this instrument formed? 463. How is the hydrometer prepared for use?

464. If plunged into a fluid lighter than water, it will sink below the mark, and, consequently, the fluid will rise higher on the scale. If the fluid is heavier than water, the scale will rise above the surface in proportion, and thus it is ascertained in a moment whether any fluid has a greater or less specific gravity than water.

To know precisely how much the fluid varies from the standard, the scale is marked off into degrees, which indicate grains by weight, so that it is ascertained very exactly how much the specific gravity of one fluid differs from that of another.

465. Water being the standard by which the weights of other substances are compared, it is placed as the unit, or point of comparison, and is, therefore, 1, 10, 100, or 1,000, the ciphers being added whenever there are fractional parts expressing the specific gravity of the body. It is always understood, therefore, that the specific gravity of water is 1, and when it is said a body has a specific gravity of 2, it is only meant that such a body is, bulk for bulk, twice as heavy as water.

466. If the substance is lighter than water, it has a specific gravity of 0, with a fractional part. Thus, alcohol has a specific gravity of 0,809, that is, 809, water being 1,000.

467. By means of this instrument, it can be told with great accuracy how much water has been added to spirits, for the greater the quantity of water, the higher will the scale rise above the surface.

The adulteration of milk with water, can also be readily detected with it, for as new milk has a specific gravity of 1,032, water being 1,000, a very small quantity of water mixed with it would be indicated by the instrument.

THE SIPHON.

468. Take a tube bent like the letter U, and, having filled it with water, place a finger on each end, and in this state plunge one of the ends into a vessel of water, so that the end in the water shall be a little the highest; then remove the fingers and the liquid will flow out, and continue to do so until the vessel is exhausted.

469. A tube acting in this manner is called a *siphon*, and is

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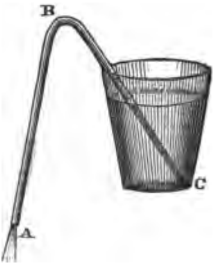
464. How is it known by this instrument whether the fluid is lighter or heavier than water? 465. What is the standard by which the weights of other bodies are compared? What is the specific gravity of water? When is it said that the specific gravity of a body is 2 or 4, what meaning is intended to be conveyed? 466. If alcohol has a specific gravity of 809, what, in reference to this, is the specific gravity of water? 467. In what cases will the hydrometer detect fraud? 468. In what manner is a siphon made? 469. Explain the reason why the water ascends through one leg of the siphon, and descends through the other?

FIG. 14.

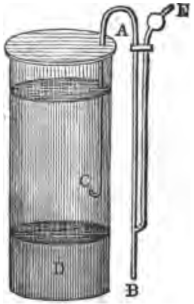


Siphon.

represented by *Fig.* 114. The reason why the water flows from the end of the tube, A, and, consequently, ascends through the other part, is, that there is a greater weight of the fluid from B to A, than from C to B, because the perpendicular height from B to A, is the greatest. The weight of the water from B to A, falling downward by its gravity, tends to form a vacuum, or void space, in that leg of the tube; but the pressure of the atmosphere on the water in the vessel, constantly forces the fluid up the other leg of the tube, to fill the void space, and thus the stream is continued as long as any water remains in the vessel.

470. *Chemical Siphon.* This is designed to draw off the liquid without disturbing the sediment at the bottom of the vessel. It consists of the bent tube, B, C, with the end, C, turned upward. To use it, place the finger on B, and introduce C, into the liquid, not so deep as to reach the sediment, D, then draw the air by suction, from E, and on removing the finger, the liquor will flow out at B. This is a highly convenient instrument.

FIG. 115.



Chemical Siphon.

471. *Application of the Siphon.*—The siphon is employed in draining mines, when there is a sufficient fall in the vicinity: it may also be used to convey water over a hill, provided the place where it is wanted is a foot or two lower than the fountain.

For this purpose, let A be a spring, *Fig.* 116, situated behind a hill, and it is desired to bring the water to B, for family use. To do this, a lead tube, with a stop-cock at C, is carried over the hill, having also a stop-cock at each end. This done, and the two ends being closed, fill the two legs of the tube by pouring in water at C; then C being closed, let one person open the stop-cock at B, and a moment after, open that at A, and the water will instantly begin

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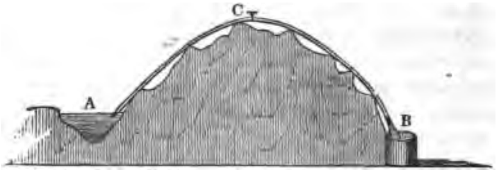
471. Explain by Fig. 116, how the siphon conveys water over a hill.

FIG. 116.



Application of the Siphon.

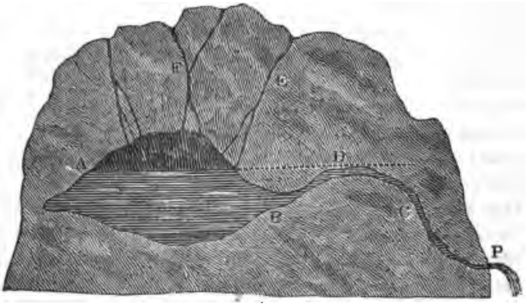
to flow from the spring to the reservoir, and if C, is kept closed, will continue to run so long as the fountain furnishes water.

The principle of the siphon has been explained under *Fig.* 114.

INTERMITTING SPRINGS.

472. The action of the siphon depends upon the same principle as the action of the pump, namely, the pressure of the atmosphere, and therefore, its explanation properly belongs to Pneumatics. It is introduced here merely for the purpose of illustrating the phenomena of intermitting springs, a subject which belong to Hydrostatics.

FIG. 117.



Intermitting Spring.

Some springs, situated on the sides of mountains, flow for a while, with great violence, and then cease entirely. After a

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472. What is an intermitting spring? 473. How is the phenomenon of the intermitting spring explained?

time they begin to flow again, and then suddenly stop, as before. These are called *intermitting springs.* Among ignorant and superstitious people, these strange appearances have been attributed to witchcraft, or the influence of some supernatural power. But an acquaintance with the laws of nature will dissipate such ill-founded opinions, by showing that they owe their peculiarities to nothing more than natural siphons, existing in the mountains from whence the water flows.

473. *Fig.* 117 is the section of a mountain and spring, showing how the principle of the siphon operates to produce the effect described. Suppose there is a crevice, or hollow, in the rock from A to B, and a narrow fissure leading from it, in the form of the siphon B C, The water from the rills, F E, filling the hollow, up to the line, A D, it will then discharge itself through the siphon, and continue to run until the water is exhausted down to the leg of the siphon B, when it will cease. Then the water from the rills continuing to run until the hollow is again filled up to the same line, the siphon again begins to act, and again discharges the contents of the reservoir as before, and thus the spring, P, at one moment flows with great violence and the next moment ceases entirely.

The hollow, above the line A D, is supposed not to be filled with water at all, since the siphon begins to act whenever the the fluid rises up to the bend, D.

During the dry seasons of the year, it is obvious, that such a spring would cease to flow entirely, and would begin again only when the water from the mountain filled the cavity through the rills.

CHAPTER VI.

HYDRAULICS.

474. *It has been stated,* (411,) *that Hydrostatics is that branch of Natural Philosophy, which treats of the weight, pressure, and equilibrium of fluids, and that Hydraulics has for its object, the investigation of the laws which regulate the fluids in motion.*

If the pupil has learned the principles on which the pressure

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Explain Fig. 117, and show the reason why such a spring will flow and cease to flow, alternately. 474. How does the science of Hydrostatics differ from that of Hydraulics?

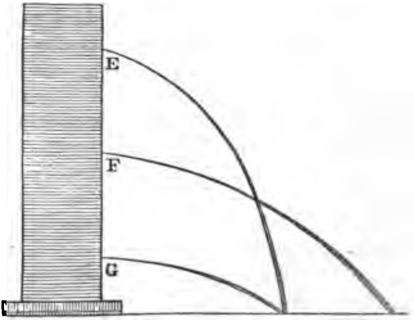
and equilibrium of fluids depend, as explained under the former article, he will now be prepared to understand the laws which govern fluids when in motion.

475. The pressure of water downward, is in the same proportion to its height, as is the pressure of solids in the same direction.

476. Suppose a vessel of three inches in diameter has a billet of wood set up in it, so as to touch only the bottom, and suppose the piece of wood to be three feet long, and to weigh nine pounds; then the pressure on the bottom of the vessel will be nine pounds. If another billet of wood be set on this, of the same dimensions, it will press on its top with the weight of nine pounds, and the pressure at the bottom will be eighteen pounds, and if a like billet be set on this, the pressure at the bottom will be twenty-seven pounds, and so on, in this ratio, to any height the column is carried.

Now the pressure of fluids is in the same proportion; and when confined in pipes, may be considered as one short column set on another, each of which increases the pressure of the lowest in proportion to their number and height.

FIG. 118.



Velocity and Gravity.

477. If a vessel, *Fig.* 118, be filled with water, and three apertures be made in its side at E F G, the fluid will be thrown out in jets, falling to the earth in the curved lines shown. The reason why these curves differ in shape, is, that the fluid is acted on by the two forces, namely, the pressure of the water above the jet, which produces its velocity forward, and the action of gravity, which impels it downward. It therefore obeys the same laws that solids do when projected forward, and falls

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475. Does the downward pressure of water differ from the downward pressure of solids, in proportion? 476. How is the downward pressure of water illustrated? Why do the lines described by the jets from the vessel, Fig. 118, differ in shape? What two forces act upon the fluid as it is discharged, and how do these forces produce a curved line?

down in curved lines, the shapes of which depend on their relative velocities, (245.)

478. The quantity of water discharged, being in proportion to the pressure when the orifices are the same, that discharged from each orifice will differ in quantity, according to the height of the water above it.

479. It is found, however, that the velocity with which a vessel discharges its contents, does not depend entirely on the pressure, but in part on the kind of orifice through which the liquid flows. It might be expected, for instance, that a tin vessel of a given capacity, with an orifice of, say an inch in diameter, would part with the contents sooner than another of the same capacity and orifice, whose side was an inch or two thick, since the friction through the tin might be considered much less than that presented by the other orifice.

480. But it has been found, by experiment, that the tin vessel does not part with its contents so soon as another vessel, of the same height and size of orifice, from which the water flowed through a short pipe. And, on varying the length of these pipes, it is found that the most rapid discharge, other circumstances being equal, is through a pipe, whose length is twice the diameter of its orifice. Such an aperture discharged 82 quarts, in the same time that another vessel of tin, without the pipe, discharged 62 quarts.

481. This surprising difference is accounted for, by supposing that the cross currents, made by the rushing of the water from different directions toward the orifice, mutually interfere with each other, by which the whole is broken, and thrown into confusion by the sharp edge of the tin, and hence the water issues in the form of spray, or of a screw, from such an orifice. A short pipe seems to correct this contention among opposing currents, and to smooth the passage of the whole, and hence we may observe, that from such a pipe, the stream is round and well defined.

482. *Proportion between the Pressure and the Velocity of Discharge.*—If a small orifice be made in the side of a vessel filled with any liquid, the liquid will flow out with a force and velocity equal to the pressure which the liquid before exerted on that portion of the side of the vessel before the orifice was made.

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478. In what proportion do the orifices discharge the fluid? 479. Does the velocity with which a fluid is discharged, depend entirely on the pressure? 480. What circumstance, besides pressure, facilitates the discharge of water from an orifice? In a tube discharging water with the greatest velocity, what is the proportion between its diameter and its length? What is the proportion between the quantity of fluid discharged through an orifice of tin and through a short pipe? 481. How is this difference explained? 482 What are the proportions between the velocities of discharge and the heights of the orifices, as above explained?

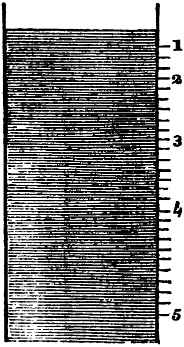
Now, as the pressure of fluids is as their heights, it follows, that if several such orifices are made, the lowest will discharge the greatest, while the highest will discharge the least quantity of the fluid.

The velocity of discharge, in the several orifices of such a vessel, will show a remarkable coincidence between the ratio of increase in the quantity of liquid, and the increased velocity of a falling body.

483. Thus, if the tall vessel, *Fig.* 119, of equal dimensions throughout, be filled with the water, and a small orifice be made at one inch from the top, or below the surface, as at 1; and another at 2, 4 inches below this; another at 9 inches; a fourth at 16 inches; and a fifth at 25 inches; then the velocities of discharge, from these several orifices, will be in proportion of 1, 2, 3, 4, 5.

484. To make this more obvious, we will place the expressions of the several velocities in the upper line of the following table, the lower numbers expressing the depths of the several orifices.

FIG. 119.



Velocity of Discharge.

Velocity,....	1	2	3	4	5	6	7	8	9	10
Depth,......	1	4	9	16	25	36	49	64	81	100

Thus it appears, as in falling bodies, that to produce a twofold velocity a fourfold height is necessary. To obtain a threefold velocity of discharge, a ninefold height is required, and for a fourfold velocity, sixteen times the height, and so in this proportion, as shown by the table, (114.)

In order to establish the fact, that the velocity with which a liquid spouts from an orifice, is equal to the velocity which a body would acquire in falling unobstructed from the surface of the liquid to the depth of the orifice, it is only necessary to prove the truth of the principle in any one particular case.

Now it is manifestly true, if the orifice be presented downward, and the column of fluid over it be of small height, then this indefinitely small column will drop out of the orifice by the mere effect of its own weight, and, therefore, with the

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483. If in Fig. 119, orifices are made at the distance of 1, 4, 9, 16, and 25 inches from the top, then in what ratio of velocity will the water be discharged? 484. How is it proved that the velocity of the spouting liquid is equal to that of a falling body?

same velocity as any other falling body; but as fluids transmit pressure in all directions, the same effect will be produced, whatever may be the direction of the orifice.

FRICTION BETWEEN SOLIDS AND FLUIDS.

485. The rapidity with which water flows through pipes of the same diameter, is found to depend much on the nature of their internal surfaces. Thus a lead pipe, with a smooth aperture, under the same circumstances, will convey much more water than one of wood, where the surface is rough, or beset with points. In pipes, even where the surface is as smooth as glass, there is still considerable friction, for in all cases, the water is found to pass more rapidly in the middle of the stream than it does on the outside, where it rubs against the sides of the tube.

486. The sudden turns, or angles of a pipe, are also found to be a considerable obstacle to the rapid conveyance of the water, for such angles to throw the fluid into eddies or currents by which its velocity is arrested.

In practice, therefore, sudden turns are generally avoided, and where it is necessary that the pipe should change its direction, it is done by means of as large a circle as convenient.

487. *Water in Pipes.*—Where it is proposed to convey a certain quantity of water to a considerable distance in pipes, there will be a great disappointment in respect to the quantity actually delivered, unless the engineer takes into account the friction, and the turnings of the pipes, and makes large allowances for these circumstances. If the quantity to be actually delivered ought to fill a two-inch pipe, one of three inches will not be too great an allowance, if the water is to be conveyed to any considerable distance.

In practice, it will be found that a pipe of two inches in diameter, one hundred feet long, will discharge about five times as much water as one of one-inch in diameter of the same length, and under the same pressure.

488. This difference is accounted for, by supposing that both tubes retard the motion of the fluid, by friction, at equal distances from their inner surfaces, and consequently that the effect of this cause is much greater in proportion, in a small tube, than in a large one.

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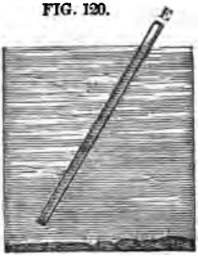
485. Suppose a lead and a glass tube, of the same diameter; which will deliver the greatest quantity of liquid in the same time? Why will a glass tube deliver most? 486. What is said of the sudden turnings of a tube, in retarding the motion of the fluid? 487 How much more water will a two-inch tube of a hundred feet long discharge, than a one inch tube of the same length? 488. How is this difference accounted for?

489. *Flowing of Rivers.*—The effect of friction in retarding the motion of fluids is perpetually illustrated in the flowing of rivers and brooks. On the side of a river, the water, especially where it is shallow, is nearly still, while in the middle of a stream it may run at the rate of five or six miles an hour. For the same reason, the water at the bottoms of rivers is much less rapid than at the surface. This is often proved by the oblique position of floating substances, which in still water would assume a vertical direction.

Thus, suppose the stick of wood E, *Fig.* 120, to be loaded at one end with lead, of the same diameter as the wood, so as to make it stand upright in still water. In the current of a river, where the lower end nearly reaches the bottom, it will incline as in the figure, because the water is more rapid toward the surface than at the bottom, and hence the tendency of the upper end to move faster than the lower one, gives it an inclination forward.

FIG. 120.



River Current

MACHINES FOR RAISING WATER.

490. The common pump, though a hydraulic machine, depends on the pressure of the atmosphere for its effect, and therefore its explanation comes properly under the article Pneumatics, where the consequences of atmospheric pressure will be illustrated.

Such machines only as raise water without the assistance of the atmosphere, come properly under the present article.

491. ARCHIMEDES' SCREW.—Among these, one of the most curious, as well as ancient machines, is the *screw of Archimedes*, and which was invented by that celebrated philosopher, two hundred years before the Christian era, and then employed for raising water, and draining land in Egypt.

492. It consists of a tube, made of lead, or strong leather, coiled round a cylinder of wood or iron, as represented by *Fig.* 121. It has support at each end, turning on gudgeons, the upper end being sometimes furnished with cog-wheels to give a more easy and rapid motion. Both ends are open, the lower

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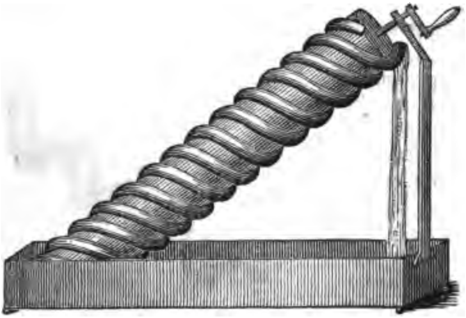
489. How do rivers show the effect of friction in retarding the motion of their waters? Explain Fig. 120. 490. What is said of the common pump? 491. Who is said to have been the inventor of Archimedes' screw? When was this screw invented? 492. Explain this machine, as represented in Fig. 110, and show how the water is elevated by turning it

one being placed so far under the water as not to allow the orifice to come above the surface in turning; the other discharges the water in an uninterrupted stream.

493. The angle at which these machines work depends on the manner of winding the tube on the cylinder; that is,

FIG. 121.



Archimedes' Water Screw.

whether the folds touch each other, or are at a distance apart, for it is obvious that if the tube passes only a few times around the support, this must be in too nearly a horizontal position to act; but if the folds nearly touch, as in the figure, it may be placed at an angle of about 50° with the horizon. It will be apparent that the direction of each fold must be toward the horizon, as the screw turns, otherwise the water would not run. This is shown by the figure. This machine, as above stated, is a very ancient invention, but has been re-invented in modern times, and employed in most parts of Europe.

It has been constructed in various ways besides that here represented. One was, to cut a spiral groove in a large log of wood, and cover this with metal, leather, or boards, so as to make it hold the water. The screw being thus sunk into the wood, instead of being on the outside, as commonly represented.

494. When it was necessary to raise the water to a great height, a series, one obliquely above the other, were employed, platforms being constructed, with vessels to contain the water, the lower end of the second screw taking that which was elevated by the first; the third receiving that carried up by the second, and so on. At present we believe this engine is no-

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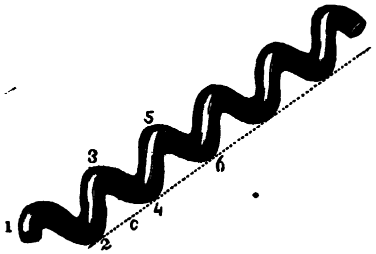
493. What must be the inclination of this machine? 494. How was water raised to great heights by this machine?

where used except as a curiosity, there being better means of raising water.

495. This principle is readily illustrated by winding a piece of lead tube round a walking-stick, and then turning the whole with one end in a dish of water, as shown in the figure.

Theory of Archimedes' Screw.—By the following cut and explanation, the manner in which this machine acts will be understood.

FIG. *a*.



496. Suppose the extremity 1, *Fig. a* to be presented upward, as in the figure, the screw itself being inclined as here represented. Then, from its peculiar form and position, it is evident, that commencing at 1, the screw will descend until we arrive at a certain point, 2; in proceeding from 2 to 3, it will ascend. Thus, 2 is a point so situated that the parts of the screw on both sides of it ascend, and therefore if any body, as a ball, were placed in the tube at 2, it could not move in either direction without ascending. Again, the point 3 is so situated, that the tube on each side of it descends; and as we proceed we find another point, 4, which, like 2, is so placed, that the tube on both sides of it ascends, and, therefore, a body placed at 4, could not move without ascending. In like manner, there is a series of other points along the tube, from which it either descends or ascends, as is obvious by inspection.

Now let us suppose a ball, less in size than the bore of the tube, so as to move freely in it, to be dropped in at 1. As the tube descends from 1 to 2, the ball of course will descend down the to 2, where it will remain at rest.

Next, suppose the ball to be fastened to the tube at 2, and suppose the screw to be turned nearly half round, so that the end 1 shall be turned downward, and the point 2 brought to highest point of the curve 1, 2, 3.

497. The last movement of the spiral, it is evident, would so

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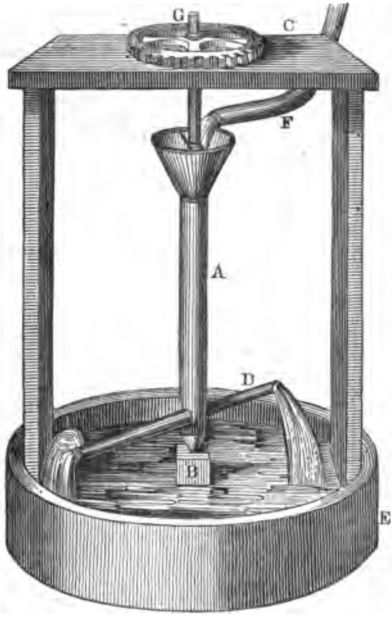
495. How may the principle of Archimedes' screw be readily illustrated? 496. Explain the manner in which a ball would ascend, Fig. *a*, by turning the screw. 497. On what property of fluids does the ascent of the water depend?

change the positions of the ascending and descending parts, as to continue the motion upward, but it must be remembered that the water differs from the ball used for illustration, in having a constant pressure downward, and consequently upward, and that the ascent of the water depends on this property of the action of fluids.

498. **Barker's Mill.**—For the different modes of applying water as a power for driving mills, and other useful purposes, we must refer the reader to works on practical mechanics.

FIG. 122.



Centrifugal Mill.

There is, however, one method of turning machinery by water, invented by Dr. Barker, which is strictly a philosophical, and, at the same time, a most curious invention, and therefore is properly introduced here.

This machine is called *Barker's centrifugal mill*, and such

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498. Describe Barker's centrifugal mill, Fig. 122

parts of it as are necessary to understand the principle on which it acts are represented by *Fig.* 122.

The upright cylinder A, is a tube which has a funnel-shaped mouth for the admission of the stream of water from the pipe, F. This tube is six or eight inches in diameter, and may be from ten to twenty feet long. The arms, D, are also tubes communicating freely with the upright one, from the opposite sides of which they proceed. The shaft, G, is firmly fastened to the inside of the tube, openings at the same time being left for the water to pass to the arms, D. The lower part of the tube is solid, and turns on a point resting on a block of stone or iron, B. The arms are closed at their ends, near which are the orifices on the sides opposite to each other, so that the water spouting from them will fly in opposite directions. The stream from the pipe, F, is regulated by a stop-cock, so as to keep the tube A, constantly full without overflowing.

499. To set this engine in motion, nothing is required but the force of the water, which being let in by the pipe, descends, and spouting from the opposite orifices, the motion immediately begins, and if the main tube is of sufficient length, and kept full of water, it will in a few minutes acquire a whirling velocity which will astonish any one who has not before seen this curious machine.

500. With respect to the theory of its motion, Euler, Gregory, Brande, and others, have written; and it was formerly supposed to depend in part on the resistance of the atmosphere, but on trial it is said to revolve most rapidly in a vacuum. It is therefore difficult to explain very clearly on what its motion does depend. Dr. Gregory says, "In this machine the water does not act by its weight, or momentum, but by its centrifugal force, and the reaction that is produced by the flowing of the water on the point immediately behind the orifice of discharge." Dr. Brande says, "The resistance, or reaction generated by the water issuing from the holes, is such as to throw the vertical pipe with its arms and axis into rapid rotary motion."

A model of the running part of this mill may be made by any tinner, for a few shillings, and may be kept in constant motion, as a curiosity, by the waste water from the water-ram described a few pages hence. The shaft may be from two to four feet in length, and an inch or two in diameter, the arms being one-half or one-third this size. The orifices in the arms must be small, otherwise too much water will be required, the quantity discharged being much greater than might be supposed.

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499. How is this mill set in motion? **500.** What is the theory of Barker's mill?

After a few revolutions, the machine will receive an additional impulse by the centrifugal force generated in the arms, and in consequence of this, a much more violent and rapid discharge of the water takes place, than would occur by the pressure of that in the upright tube alone. The centrifugal force, and the force of the discharge thus acting at the same time, and each increasing the force of the other, this machine revolves with great velocity and proportionate power. The friction which it has to overcome, when compared with that of other machines, is very slight, being chiefly at the point C, where the weight of the upright tube and its contents is sustained.

By fixing a cog-wheel to the shaft at G, motion may be given to any kind of machinery required.

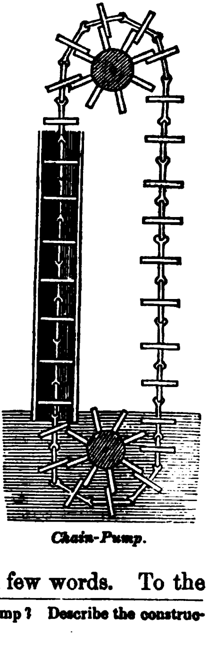
Where the quantity of water is small, but its height considerable, this machine may be employed to great advantage, it being under such circumstances one of the most powerful engines ever invented.

CHAIN–PUMP.

501. The principle of this machine is ancient, but instead of flat boards, as in *Fig.* 123, pots, or deep buckets, were employed. Such engines are numerous along the banks of the Nile, and in Nubia and Hindostan, at the present day.

The construction, as well as the action of the chain-pump, will be understood by the figure. It consists of a number of square pieces of board, or of thin iron, connected together through their centers by iron rods, so that they can have no lateral motion. These rods are fastened to each other by hooks and eyes, thus forming a chain with long links. The ascending side of this chain passes through a square box, to which these pieces or buckets are closely fitted, but not so as to create much friction. The lower wheel, as well as the lower end of the box, must be placed below the surface of the water to be raised.

FIG. 123.



Chain-Pump.

The action of this machine is described in few words. To the

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501. What is said of the antiquity and use of the chain-pump? Describe the construction and action of this machine.

upper wheel is attached a crank; or if large quantities of water are to be raised, as on board of ships, mill work is added, to multiply the motion of the wheel, in order to give the buckets, a more rapid ascent through the box. As the end of the box is constantly under the water, every board necessarily carries up a portion in its ascent, and although a single bucket would elevate but a small quantity up to the end of the box, yet as they follow each other in rapid succession, a constant stream is produced, and thus, when the trunk is a foot in diameter, and the power is sufficient, it will be obvious that a large quantity of water may, in a short time, be elevated by this means.

502. Although this machine is called a *pump*, it will be observed that the atmosphere is not concerned in its action.

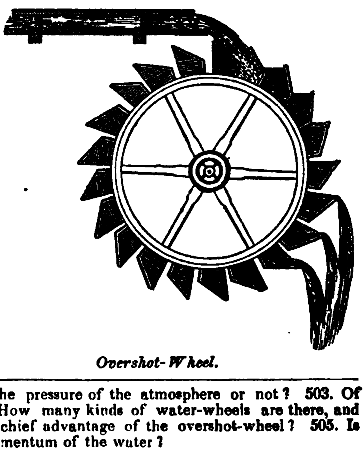
WATER-WHEELS.

503. Water-wheels generally consist of a drum, or hollow cylinder, revolving on an axis, while the diameter or exterior surface is covered with *flat-boards*, *vanes*, or cavities called *buckets*, upon which the water acts; first, to give motion to the wheel, and then to machinery. Such wheels are of three kinds, namely: the *overshot*, *undershot*, and *breast*-wheels.

504. *Overshot-Wheel.*—This wheel of all others, gives the greatest power with the least quantity of water, and is, therefore, generally used when circumstances will permit, or where there is a considerable fall, with a limited quantity of water.

505. The overshot-wheel, *Fig.* 124, requires a fall equal at least to its own diameter, and it is customary to give it a greater length than other wheels, that the cells or buckets may contain a large quantity of water, for it is chiefly by the weight, and not the momentum of the fluid that this wheel is turned.

FIG. 124.



Overshot-Wheel.

506. In its construction, the drum, or cir-

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502. Does the chain-pump act by the pressure of the atmosphere or not? 503. Of what do all water-wheels consist? How many kinds of water-wheels are there, and what are their names? What is the chief advantage of the overshot-wheel? 505. Is this wheel turned by the weight or momentum of the water?

cumference is made water-tight, and to this are fixed narrow troughs or buckets, formed of iron, or boards running the whole length of the drum. The water is conducted by a trough nearly level, and sometimes in width equal to the length of the wheel. It falls into the buckets on the top of the wheel, and hence the name *overshot.*

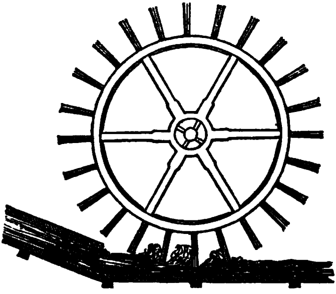
507. The buckets are so constructed as to retain the water until the wheel has made about one third of a revolution from the place of admission, when it escapes as from an inverted vessel, and the wheel ascends with empty buckets, while on the opposite side they are filled with water, and thus the revolution is perpetuated. This whole machine and its action are so plain and obvious as to require no particular reference.

508. From the experiments of Mr. Smeaton, it appears, that the fall and quantity of water, and the diameter of the wheel being the same, the overshot, will produce about double the effect of the undershot-wheel.

509. *Undershot-Wheel.*—This is so called because the water passes *under* instead of *over* the circumference, as in that above described. Hence it is moved by the momentum, not the weight of the water.

510. Its construction, as shown by *Fig.* 125, is different from the overshot, since instead of tight buckets to retain the water, it has *flat-boards*, standing like rays around the circumference.

FIG. 125.



Undershot-Wheel.

511. Thus constructed, this wheel moves equally well whether the water acts on one or the other side of the boards, and hence is employed for tide-wheels, which turn in one direction when the tide is going out, and in the other when it is coming in.

This wheel requires a rapid flow, and a large quantity of water, to give it an efficient motion.

512. *Breast-Wheel.*—This wheel, in its construction, or

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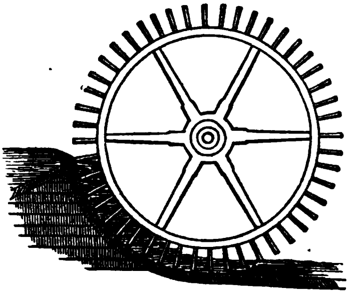
506. Describe its construction. **507.** What is said of the construction of the buckets? **508.** Circumstances being equal, how much greater power has the overshot than the undershot-wheel? **509.** Where does the water pass in the undershot-wheel? What kind of force moves this wheel? **510.** How does its construction differ from the over shot wheel? What is a tide-wheel?

rather in the application of the moving power, is between the two wheels already described. In this the water, instead of passing over, or entirely under the wheel, is delivered in the direction of its center, *Fig.* 126. This is one of the most common wheels, and is employed where there is not a sufficient fall for the construction of the overshot kind.

FIG. 126.



Breast-Wheel.

513. The breast-wheel is moved partly by the weight, and partly by the momentum of the water. But notwithstanding this double force, this wheel is greatly inferior to the overshot, in effect, not only because the lever power is diminished by the smaller diameter, but also on account of the great waste of water which always attends the best constructed wheels of this kind.

514. *General Remarks.*—In order to allow any of the above wheels to act with freedom, and to their fullest power, it is absolutely necessary that the water which is discharged, at the bottom of the wheel should have a wide and uninterrupted passage to run away, for whenever this is not the case it accumulates and forms a resistance to the action of the buckets or flat-boards, and thus substracts just so much from the velocity and power of the machine.

515. HYDRAULIC OR WATER-RAM.—This beautiful engine was invented by Montgolfier, a Frenchman, (and the same who first ascended in a balloon,) in about 1796.

The form and construction of this useful machine, which is very simple in all its parts, will be understood by *Fig.* 127. Suppose the pipe A, comes from a spring, elevated a few feet above the horizontal line B, and that it conveys a constant stream of water. At the termination of this pipe, there is a valve, called a *spindle* valve, capable of closing its orifice when drawn upward; on the spindle *t*, are several small weights, by which the valve is made to drop down and remain open when

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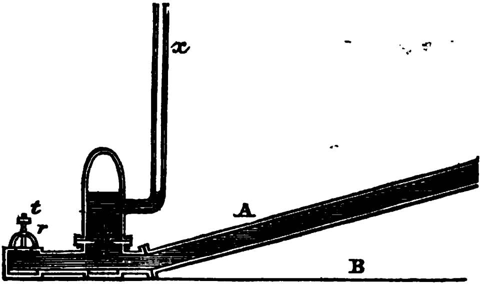
512. How does the breast-wheel differ from the overshot and undershot-wheels? Where does the water strike this wheel? 513. By what power is the breast-wheel moved? Why is this wheel inferior to the overshot? 514. What cautions are necessary in order to permit any of the wheels described to produce their full effects? 515. Who invented the hydraulic or water-ram? Explain its construction by Fig. 127.

FIG. 127.



Hydraulic or Water-Ram.

the water is still; the weight of the whole being so nicely adjusted, that the movement of the running water will elevate it to its place, and thus stop the discharge. The weight of this valve, a nice point in the construction of the machine, must be just sufficient to make it rise by the force of the stream, and sink again when the water ceases to flow, thus rising and falling, and in effect causing the fluid to stop for an instant, and then renew its motion.

516. Now water in motion acquires a momentum in proportion to the length of the column, and the height of the source, and when in action exerts a force equal to that of a solid body of the same length and gravity, pressing downward from the same elevation. The inelasticity of the fluid gives it the property of acquiring motion through the whole length of a tube elevated at one extremity, whenever only a small portion is allowed to escape by its own pressure. Hence, when the valve opens, by dropping down, all the water in the pipe, however long it may be, instantly moves forward to supply the place of that which has thus escaped; and, if the pipe is long and the fountain high, ordinary metallic conductors are burst asunder by the shock whenever the stream is interrupted. It is on these principles of the force of water that the Hydraulic Ram is founded; for, when the stream is stopped by the rising of the valve, as already explained, an outlet is provided by another valve, *u*, opening upward into an air vessel, having a discharging pipe, *x*, and consequently when the spindle valve, *t*, is closed, this valve instantly opens, and the water is thrown

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516. On what does the momentum of water in a tube depend? What is said of the motion of the water in the tube?

with great force into the air-vessel, and, through the discharging-pipe, to the place where it is wanted. The stream being thus interrupted, and the water becoming still under the lower valve, this instantly opens by falling down, thus allowing the fluid to discharge itself at *r*, when the motion again raises the valve, and it is stopped, the valve *u* being raised for its escape, as before; and thus this curious machine, if well constructed, will act with no other power or help, but a little stream of water, for weeks or months.

517. This engine affords the most efficient, cheap, and convenient means of raising water, for ornamental or farming purposes, ever invented. A spring on a hill near the house, or a running brook, with an elevation of a few feet, is all the power required to supply an abundance of water for any private or even public establishment. Mr. Millington, who erected many of these machines in England, states that a very insignificant pressing column is capable of raising by the water-ram, a very high ascending one, so that a sufficient fall may be obtained in almost any running brook, by erecting a dam at its upper end to produce a reservoir, and then carry the pipe down the natural channel until a sufficient fall is obtained. In this way, a ram was made to raise one hundred hogsheads of water to the height of 134 feet in 24 hours, with a fall of 4½ feet.

518. *Deaf and Dumb Asylum.*—The Deaf and Dumb Asylum, of Hartford, Ct., is supplied with water by means of Hydraulic Rams, of which there are three, in case of accidents, though only two are kept in motion. The water is brought from the Little River, at the distance of half a mile, and is raised to the fourth story of the edifice, a height of 140 feet. The quantity delivered by two rams is about 35 hogsheads per day. The cost of the apparatus, including the stone structure for the rams and inclined tubes, was nearly $1,200.

CHAPTER VII.

PNEUMATICS.

519. ***The term Pneumatics is derived from the Greek, pneuma, which signifies breath or air. It is that science which***

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517. What is said of the economy and convenience of the water-ram? To what heights will it throw water in proportion to the fall? 519. What is meant by pneumatics?

investigates the mechanical properties of air and other elastic fluids.

Under the article *Hydrostatics*, (411,) it was stated that fluids were of two kinds, namely, *elastic*, and *non-elastic*, and that air and the gases belonged to the first kind, while water and other liquids belonged to the second.

520. The atmosphere which surrounds the earth, and in which we live, and a portion of which we take into our lungs at every breath, is called *air*, while the artificial products which possess the same mechanical properties are called *gases*.

When, therefore, the word *air* is used in what follows, it will be understood to mean the atmosphere which we breathe.

521. *Air in all Porous Substances.*—Every hollow, crevice or pore, in solid bodies, not filled with a liquid, or some other substance; appears to be filled with air; thus, a tube of any length, the bore of which is as small as it can be made, if kept open, will be filled with air; and, hence, when it is said that a vessel is filled with air, it is only meant that the vessel is in its ordinary state. Indeed, this fluid finds its way into the most minute pores of all substances, and cannot be expelled and kept out of any vessel, without the assistance of the air-pump, or some other mechanical means.

522. *Elasticity of Air.*—By the *elasticity* of air is meant its spring, or the force with which it reacts when compressed in a close vessel. It is chiefly in respect to its elasticity and lightness, that the mechanical properties of air differ from those of water and other liquids.

523. Elastic fluids differ from each other in respect to the *permanency* of the elastic property. Thus, steam is elastic only while its heat is continued, and, on cooling, returns again to the form of water.

524. Some of the gases, also, on being strongly compressed, lose their elasticity and take the form of liquids. But, air differs from these in being permanently elastic; that is, if it be compressed with ever so much force, and retained under compression for any length of time, it does not therefore lose its elasticity or disposition to regain its former bulk; but, always reacts with a force in proportion to the power by which it is compressed.

525. *Compression by Experiment.*—Thus, if the strong tube or barrel, *Fig.* 128, be smooth and equal on the inside, and there be fitted to it the solid piston or plug A, so as to work up and

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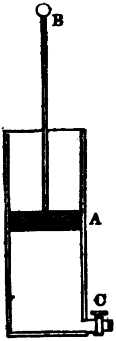
520. What is air? What is gas? **521.** What is meant when it is said that a vessel is filled with air? Is there any difficulty in expelling the air from vessels? **522.** What is meant by the elasticity of air? **523.** How does air differ from steam and some of the gases, in respect to its elasticity? **524.** Does air lose its elastic force by being compressed?

down air-tight by the handle B, the air in the barrel may be compressed into a space a hundred times less than its usual bulk; it being a general principle in Pneumatics that air is compressible in proportion to the force employed.

FIG. 128.



526. *Expansion of the Air.*—On the contrary, when the usual pressure of the atmosphere is removed from a portion of air, it expands and occupies a space larger than before; and, it is found by experiment that this expansion is in a ratio as the removal of the pressure is more or less complete. Air also expands or increases in bulk when heated.

527. If the stop-cock C, *Fig.* 128, be opened, the piston A, may be pushed down with ease, because the air contained in the barrel will be forced out at the aperture. Suppose the piston to be pushed down to within an inch of the bottom, and then the stop-cock closed, so that no air can enter below it. Now, on drawing the piston up to the top of the barrel, the inch of air will expand and fill the whole space, and, were this space a thousand times as large, it would still be filled with the expanded air, because the piston removes the pressure of the external atmosphere from that within the barrel.

It follows, therefore, that the space which a given portion of air occupies depends entirely on circumstances. If it is under pressure, its bulk will be diminished in exact proportion; and as the pressure is removed, it will expand in proportion so as to occupy a thousand or even a million times as much space as before.

528. *Weight of Air.*—Another property which air possesses is weight or gravity. This property, it is obvious, must be slight, when compared with the weight of other bodies. But, that air has a certain degree of gravity, in common with other ponderous substances, is proved by direct experiment. Thus, if the air be pumped out of a close vessel, and then the vessel be exactly weighed, it will be found to weigh more when the air is again admitted.

529. *Pressure of the Atmosphere.*—It is, however, the weight of the atmosphere which presses on every part of the earth's surface, and in which we live and move as in an ocean, that here particularly claims our attention.

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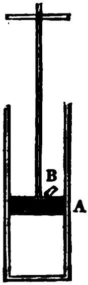
525. Explain by Fig. 128 how air may be compressed. 526. In what proportion will a quantity of air increase in bulk as the pressure is removed from it? 527. How is this illustrated by Fig. 128? 528. On what circumstances, therefore, will the bulk of a given portion of air depend? 529. How is it proved that air has weight?

The pressure of the atmosphere may be easily shown by the tube and piston, *Fig.* 129.

FIG. 129.



Suppose there is an orifice to be opened or closed by the valve *b*, as the piston A is moved up or down in its barrel. The valve being fastened by a hinge on the upper side, on pushing the piston down, it will open by the pressure of the air against it, and the air will make its escape. But, when the piston is at the bottom of the barrel, on attempting to raise it again toward the top, the valve is closed by the force of the external air acting upon it.

530. If the piston be only three inches in diameter, it will require the full strength of a man to draw it to the top of the barrel; and, when raised, if suddenly let go, it will be forced back again by the weight of the air, and will strike the bottom with great violence.

531. Supposing the surface of a man to be equal to 14½ square feet, and allowing the pressure on each square inch to be 15 lbs., such a man would sustain a pressure on his whole surface equal to nearly 14 tons.

Now, that it is the weight of the atmosphere which presses the piston down is proved by the fact that if its diameter be enlarged, a greater force, in exact proportion, will be required to raise it. And, further, if when the piston is drawn to the top of the tube, a stop-cock, as at *Fig.* 128, be opened, and the air admitted under it, the piston will not be forced down in the least, because then the air will press as much on the under as on the upper side of the piston.

532. By accurate experiments, an account of which it is not necessary here to detail, it is found that the weight of the atmosphere on every square inch of the surface of the earth is equal to fifteen pounds. If, then, a piston, working air-tight in a barrel, be drawn up from its bottom, the force employed, besides the friction, will be just equal to that required to lift the same piston, under ordinary circumstances, with a weight laid on it equal to fifteen pounds for every square inch of surface.

533. The number of square inches in the surface of a piston of a foot in diameter is 113. This being multiplied by the

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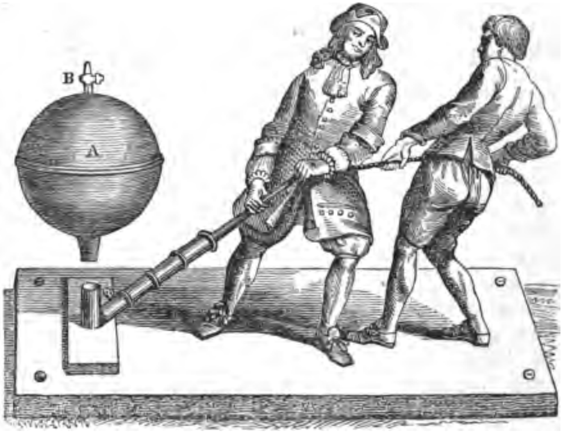
529. Explain in what manner the pressure of the atmosphere is shown by Fig. 129. 530. How is it proved that it is the weight of the atmosphere, instead of suction, which makes the piston rise with difficulty? 531. What is the pressure of the atmosphere on the surface of a man? 532. What is the pressure of the atmosphere on every square inch of surface on the earth? 533. What is the number of square inches in a circle of one foot in diameter? What is the weight of the atmosphere on the surface of a foot in diameter?

weight ot the air on each inch, which, being 15 pounds, is equal to 1,695 pounds. Thus, the air constantly presses on every surface, which is equal to the dimensions of a circle one foot in diameter, with a weight of 1,695 pounds.

THE FIRST VACUUM.

534. No doubt suction by the mouth first led to the production of a vacuum by artificial means; for, it must have been observed, long before the air-pump was thought of, that, if a tube, open at both ends, have one of them dipped in water and the other placed in the mouth, that, on drawing out the air, the water would follow.

FIG. 130.



The experiment of Otto Guericke.

535. But, the first attempt to form a vacuum by scientific means was made by the famous Otto Guericke, burgomaster of Magdeburgh, in about 1654. This was done by means of a sort of air-pump, consisting of a tube of metal, furnished with a stopcock near its lower end, and a piston with a valve opening inwards, worked by means of an iron rod.

Having a strong cask, filled with water and firmly set on legs, a foot or two from the ground, this pump was screwed to its lower end, and the piston worked until two strong men could no longer move it. But, at this period of the experiment, a difficulty happened which the philosopher had not thought of. A noise was heard in every part of the cask like that of bubbling or boiling water. This was soon found to proceed from the rush of air through all the crevices and pores of the wood, of which the cask was made; and, in a few hours, the vessel was filled with air above the water which remained. But, Guericke was not discouraged by this, and immediately set to work to procure a copper globe, through which he rightly judged the air would not permeate.

To this the pump was fixed, and, the vessel being filled with water, the experiment of drawing it off again commenced, as shown by *Fig.* 130.

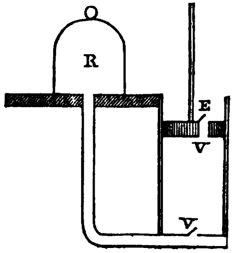
AIR—PUMP.

536. *The air-pump is an engine by which the air can be pumped out of a vessel, or withdrawn from it. The vessel so exhausted, is called a receiver, and the space thus left in the vessel, after withdrawing the air, is called a vacuum.*

The principles on which the air-pump is constructed are readily understood, and are the same in all instruments of this kind, though the form of the instrument itself is often considerably modified.

537. The general principles of its construction will be comprehended by an explanation of *Fig.* 131. In this figure, let R be a glass vessel, or *receiver*, closed at the top and open at the bottom, standing on a perfectly smooth surface, which is called the *plate* of the air-pump. Through the plate is an aperture, which communicates with the inside of the receiver and the barrel of the pump. The piston-rod works air-tight through the barrel. At the extremity of the barrel there is a valve, V, which opens upward, and is closed as the piston descends.

FIG. 131.



Air-Pump.

538. Now, suppose the piston to be drawn up, it will then leave a free communication between the receiver R, through the orifice to the pump-barrel in which the piston works. Then, if the piston be forced down, it will compress the air in the barrel

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536. What is an air-pump? **537.** Give the names of the different parts of the air-pump by Fig. 130. **538.** Show the manner in which the air-pump works to produce a vacuum between V and V′, and, in consequence, the valve E will be opened and V closed, and the air so condensed will be forced out. On drawing the piston up again, the valve E will be closed and V opened, and the external air not being permitted to enter, a partial vacuum will be formed in the barrel from V to V′. When the piston rises again, the air contained in the glass vessel, together with that in the passage between the vessel and the pump-barrel, will rush in to fill the vacuum. Thus, there will be less air in the whole space, and consequently in the receiver, than at first, because all that was contained in the barrel is forced out at every stroke of the piston. On repeating the same process, that is, drawing up and forcing down the piston, the air at each time in the receiver will become less and less in quantity, and, in consequence, more and more rarefied. For, it must be understood, that, although the air is exhausted at every stroke of the pump, that which remains, by its elasticity, expands, and still occupies the whole space.

539. Now, it will be obvious that, as the exhausting power of the air-pump depends on the expansion of the air within it, a *perfect* vacuum can never be formed by its means; for, so long as exhaustion takes place, there must be air to be forced out, and when this becomes so rare as not to force open the valves, then the process must end.

DOUBLE-ACTING AIR-PUMP.

540. The double air-pump has two similar barrels to that above described, and therefore the process of exhaustion is performed in half the time.

This is represented by *Fig.* 132, where P P are the *cylinders* of brass, in which the *pistons* work, and of which V V are the *valves*. The *piston rods*, E E, are toothed to correspond with the teeth of the *wheel* W, which is worked by the *crank* D. The *exhausting tube* T, also of brass, opens, by the valves V V, into the cylinders. This has a *stop-cock*, C, to prevent the ingress of air after the vacuum is made, in case the pistons leak. The *receiver*, R, is of glass, ground to fit air-tight to the *plate* of brass on which it stands. The exhausting tube opens at O, into the interior of the *receiver*. The *barometer tube* H, at its upper end opens into this tube, while, at the lower end, M, it is inserted into a cup of mercury.

541. The barometer tube is designed to show the degree of

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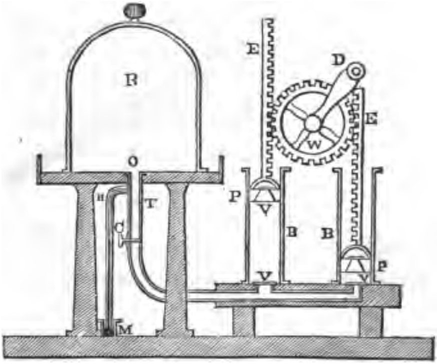
539. Will the air-pump form a perfect vacuum? Why not? 540. Name the several parts of the double-acting air-pump by Fig. 131, and show how it works. 541. What is the use of the barometer tube as applied to the air-pump?

FIG. 132.



Double-Acting Air-Pump.

exhaustion, in the receiver, with which it communicates, as shown in the figure. As the exhaustion proceeds, the external air, pressing on the mercury in the cup, elevates that in the tube, in proportion to the rarity of the air in the receiver.

Action.—The manner in which the double pump acts, is exactly similar to the single one, only that it has two barrels, or cylinders, instead of one. It is, therefore, unnecessary to repeat the explanation given under the last figure.

542. *External View of the Air-Pump.*—Having explained the principles and action of the air-pump by figures showing its interior construction, we here present the student with an external view, *Fig.* 133, of the whole machine.

543. It is a small single-barrel pump, those with more barrels being of course more complex in structure, and less easily understood. The *barrel*, A, is seven inches high and two in diameter; the *plate*, K, is eight inches in diameter; the *piston-rod*, B, works air-tight by means of the packing-screw, J, which is fitted to the *barrel-case*, I. The piston is kept perpendicular by the *guide*, E, through which it works; the *fulcrum-prop*, H, is eighteen inches high, and the *parallel rods*, D, connect the piston rod and cross-head, C, with the lever.

The dome-cap, J, contains a valve opening upward, for the escape of the air when the piston rises. This is the only valve in this pump, except that in the piston, which, as already shown,

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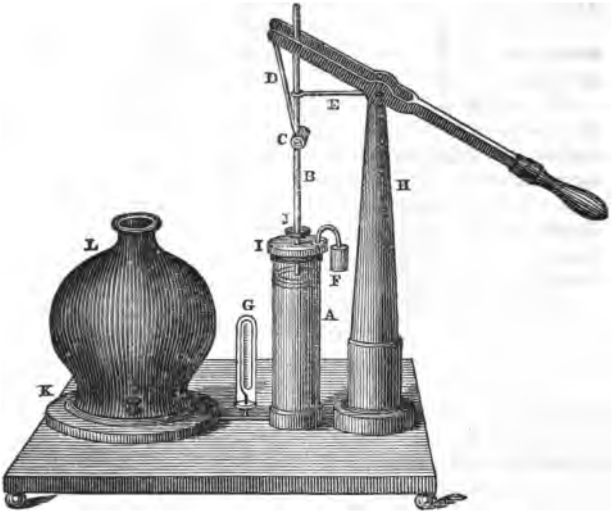
543. Explain all parts of the air-pump by Fig. 132.

FIG. 133



Single-Barrel Air-Pump.

opens to admit the expanded air from the receiver, and force it out at the upper valve. To the dome-cap, above the valve, is fitted a *curved tube*, leading to the cistern, F; its use is to receive the waste oil which may escape from that used to lubricate the piston. The globular *bell-glass*, or receiver, L, is fitted by grinding to the brass plate on which it stands; the ***barometer*** *guage*, G, contains mercury, and communicates with the tube leading from the barrel to the receiver; this shows, by its scale, what proportion of air is exhausted from the receiver; within the receiver, there is seen a protuberance, showing the end of the exhausting tube, and into which may be screwed receivers or tubes for various experiments.

544. *Experiments.*—I. If a withered apple be placed under the receiver, and the air is exhausted, the apple will swell and become plump, in consequence of the expansion of the air which it contains within the skin.

II. Ether, placed in the same situation, soon begins to boil

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544. Why does an apple placed in the exhausted receiver grow plump?

without the influence of heat, because its particles, not having the pressure of the atmosphere to force them together, fly off with so much rapidity as to produce ebullition.

III. If a bladder, partly filled with air, and the neck well secured, has the external air exhausted, that within will so expand as to burst the membrane.

IV. If a flask, partly filled with water,be placed, with its neck in a jar of the same fluid, under the receiver. the rarefied air within the flask will drive the water out; but, it will rush in again when the air is again let into the receiver.

V. If a burning taper be placed under it, the flame soon ceases for want of oxygen to support it. For the same reason, no light is seen from the collision of flint and steel in a vacuum.

VI. If a bell be struck under the receiver, the sound will grow faint as the air is exhausted, until it is no longer audible. See *Acoustics.*

CENTRIFUGAL PUMP.

545. The visitors at the London Exhibition, in 1851, were astonished at the power of the Centrifugal Pumps there in action, and recently invented by Mr. Appold.

The principle of this wonderful engine is represented by *Fig.* 134, where, suppose A A to be the well, and B B the pipe, turning on a point, and through which the water is drawn. This pipe is kept in motion by a steam engine, working a band which passes round the pulley, G. The arms or pipes, D D, open into the vertical pipe, B, the ends, E E, being also open. The pipe, B, has a valve, at C, which opens upwards. There is a trough into which the water is delivered from the arms, and which is supported by the frame, H H. From this the water escapes by the pipe, F. And, now for the action of this machine. The pipe, B, is first filled with water, which the closing of the valve, C, prevents from escaping. The machine is then set in rapid motion by the band around G, and the water in the arms is thrown out, on the same principle that the whirling of a wet mop throws the fluid from it.

The force with which the centrifugal action of the arms delivers the water is such as constantly to draw a supply from the fountain below, through the open valve C, which is closed by

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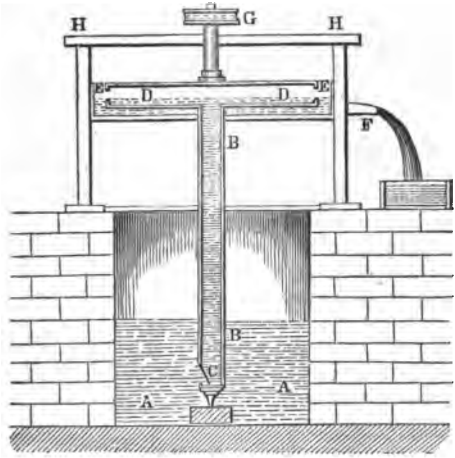
544. Why does ether boil in the same situation? Why does flame cease in a vacuum? Why is a bell inaudible in a vacuum? 545. Explain the action of the centrifugal pump

FIG. 134.



Centrifugal Pump.

the pressure of the water when the motion ceases, thus preventing the trouble of filling it again.

Size and Power of Appold's Centrifugal Pump.—The vertical tube, through which the water is drawn, as well as the arms through which it is thrown, are of various sizes, from a few inches to a foot or more in diameter. The amount of discharge, of course, depends on the velocity of the centrifugal motion, the sizes of the pipes, and the height to which the fluid is thrown. Mr. A. states that the greatest height to which it has raised water, with a one-foot pump, is 67 feet 8 inches, with 1,322 revolutions in a minute. Some of these pumps deliver 1,800 gallons of water a minute, though not to the height above mentioned.

Triumph of Science.—Probably not a case exists where the adaptation of science to the arts has met with such complete success as in this. The whole machine is based on the strictest principles of mechanical science, and yet, its construction is so simple, that few can view it without an exclamation of surprise, that its invention has been left to our own times, and not known long ago.

546. *Magdeburgh Hemispheres.*—One of the most striking illustrations of atmospheric pressure is made by means of the before

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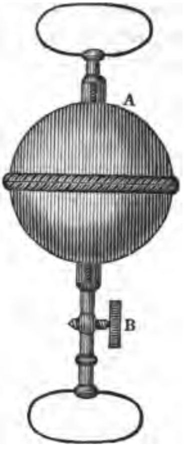
546. Describe the Magdeburgh hemispheres.

named instrument, *Fig.* 135. It consists of two hemispheres of brass, A and B, fitted to each other by grinding, so that when put together they perfectly exclude the air. When put together without preparation or in the usual manner, they hold no stronger than the parts of a snuff-box ; but when the air is exhausted from within, it will take two strong men, if the diameter of the hemispheres are six inches, to pull them apart. The air is exhausted by unscrewing the lower handle and connecting that part with the exhausting tube of the air-pump, and then by turning the key its return is prevented.

FIG. 135.



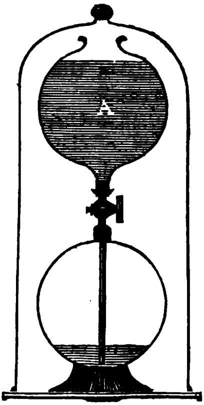
Magdeburgh Hemisphere.

547. The amount of force required to separate them, will of course depend on their diameter, and may be calculated by estimating the pressure to be equal to fifteen pounds for every square inch of surface, this, as we have seen, (532,) being the pressure of the atmosphere.

548. The same principle is involved when a piece of wet leather, with a string in the center, is pressed on a smooth stone, and then pulled by the string.

549. Expansion Fountain.—A very pretty experiment is made, with the air-pump, by means of the apparatus, *Fig.* 136.

FIG. 136.



Expansion Fountain.

It consists of two glass globes, the upper one, A, being open at the top, and furnished with a stop-cock and jet tube, reaching nearly to the bottom of the lower globe.

The lower one, being nearly filled with some colored liquid, the upper one, with the jet, is screwed to it, as seen in the figure.

Thus prepared, they are placed under the receiver of the air-pump, and as the air is exhausted, that contained in the lower

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547. What is the force required to pull them apart? 548. Why does a piece of wet leather adhere to a smooth surface? 549. Explain in what manner the fluid in the globes is made to rise or fall, at pleasure.

globe expands, and forces the liquid through the tube into the upper globe. On admitting the air into the receiver, the fluid again returns into the lower one, and this may be repeated any number of times, affording a very interesting experiment.

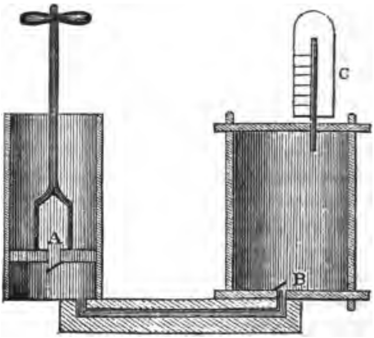
THE CONDENSER.

550. *The operation of the condenser is the reverse of that of the air-pump, and is a much more simple machine.* The air-pump, as we have just seen, will deprive a vessel of its ordinary quantity of air. The condenser, on the contrary, will double, or treble the ordinary quantity of air in a close vessel, according to the force employed.

551. The Condenser.—This instrument, *Fig.* 137, consists of a cylinder, containing a piston, and rod, with a valve A, opening downwards. From the bottom of the cylinder a tube leads to the receiver, in which the valve B, opens upwards, and from the top of the receiver there is a barometer tube and scale, C, in order to show the pressure of the air in that vessel.

Action.—On pushing down the piston, the valve A, closes, driving the air below it into the receiver through the valve B. When the piston is drawn up, the valve A, opens, while B closes, thus retaining the condensed air in the receiver. The height of the mercury in the barometer will show how many times the air in the receiver has been doubled, or how many atmospheres it contains. When any use is to be made of the condensed air, as the charging of an air-gun, there is a stop-cock fixed at the side of the receiver for this purpose.

FIG. 137.



Condenser.

552. Air-Gun.—The magazines of air-guns formerly consisted of a copper ball, which after being charged with condensed air, was screwed to the barrel, presenting an unseemly and inconvenient appendage. That here described, is a more recent and greatly improved invention.

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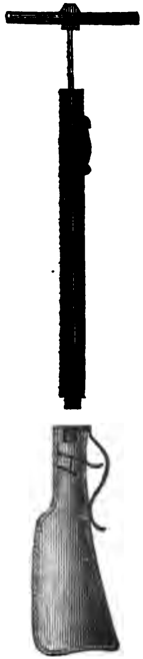
550. How does the condenser differ from the air-pump? 551. Explain Fig. 137, and show in what manner the air is condensed. 552. Explain the principle of the air-gun

FIG. 138.



Air-Gun.

In this, the breach of the gun is made of copper, and without much increasing the size, answers for the magazine, while the barrel serves as the tube of the condenser.

553. At A, *Fig.* 138, the barrel is screwed on to the breach, in which the air is condensed, by means of the piston, rod, and handle, as shown by the figure.

The piston is then withdrawn, the condensed air being prevented from escape by the valve, opening outward, as shown by the figure.

The ball being introduced, is fired by pulling back the trigger, which opens the valve, and allows a portion of the air to escape.

554. The velocity and force of the ball will depend on the amount of condensation in the magazine, and the smaller the tube and piston by which this is made, the greater of course will be the density of the confined air, and the more powerful the force by which the ball is impelled. Where the piston is no more than half or three quarters of an inch in diameter, it is said the ball will have a force not much short of that of a musket-shot.

555. *Bottle Imp.*—A curious philosophical toy, called the *Bottle Imp*, shows in a very striking manner the effects of condensing a small portion of air.

Procure a glass jar, with a neck, as represented by *Fig.* 139, also a piece of India rubber, and a string to secure it over the mouth of the jar, so that it shall be perfectly air-tight. Next, take a piece of glass tube, about three-eighths of an inch in diameter, and with a file cut off pieces an inch long, and into one end of each put a cork stopper of such size as to make most of the cork swim on the surface when the tube is placed in the water. The tubes must now be partly filled with water, so that they will just balance themselves in the fluid without sinking, the air remaining in their upper halves.

Having prepared the tubes with their corks in this manner, and placed them in the jar nearly filled with water, tie on the rubber cap with a good long string so that no air can escape, and this little apparatus is finished.

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554. With what force will the air-gun throw a ball? 555. Explain the manner of constructing the bottle imp.

Now press upon the rubber with the hand, and the floating tubes will immediately begin to descend, and will strike the bottom of the jar, one after the other, with an audible stroke, and will rise again when the pressure ceases.

Many a philosophical head, on seeing this experiment for the first time, has been puzzled to assign any cause why these little objects should fall and rise in this manner, the hand not going near them, there being several inches of air between the cap and the water.

FIG. 139.

Bottle Imp.

556. The explanation will be obvious on setting the jar between the light and the eye, and watching a tube when the pressure is made, for the water will be seen to rise in it at the moment it begins to fall, and sink again as it rises. The pressure of the hand is transmitted through the elastic rubber and air, to the water, and so to the air in the tube, which being thus condensed, takes in more water, than its buoyancy can sustain, and it sinks—rising again when the air is allowed to expand, and drive out the water.

BALLOON.

557. The first balloon was made by two brothers named Montgolfier, natives of a small village in France. It was made of linen cloth, and sent up by means of a fire of straw kindled under it, as the air thus rarefied carried it up rapidly to the height of about a mile. No one ascended with it, and it fell to the ground at the distance of a mile and a half from the place of ascent.

558. When the news of this experiment reached Paris, it created great curiosity and excitement, and the savans immediately began to take measures to have the experiment repeated there. But instead of heated air this balloon was filled with hydrogen gas. It ascended with great rapidity in sight of almost the entire population of Paris, to the height of 3,000 feet, and fell at the distance of 15 miles from the city. The experiment was completely successful, but no one as yet, had the temerity to hazard a personal adventure of so doubtful a nature.

559. In a few months, however, a young man of Paris,

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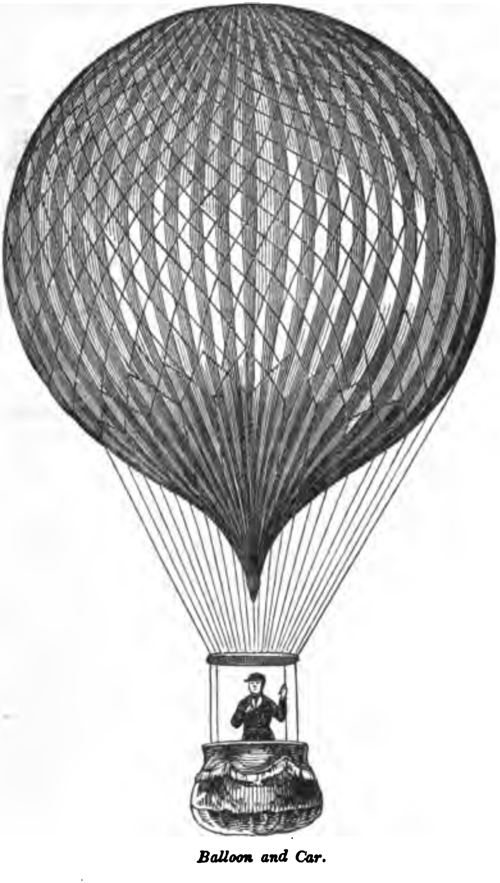
556. Explain the reason why the floats in the water-imp are influenced by the pressure
557. Who first made a balloon? With what was it filled?

FIG. 140.



Balloon and Car.

named Rosier, ascended in a hot-air balloon, and the next year the celebrated Charles, ascended in a hydrogen balloon to the height of 3,000 feet, and fell at the distance of 25 miles from Paris in safety.

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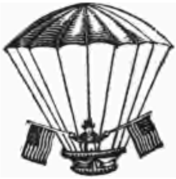
559. What gas was afterwards used to fill balloons? Who first went up in a hydrogen balloon?

These were the origin of balloon ascensions, which have now become so common in most parts of the world.

560. *Construction of Balloons.*—Most balloons as now constructed, consist of globular bags of oiled, or varnished silk, over which is thrown a netting of cords, ending in ropes, to which the parachute and car in which the aerial voyager sits, are attached, *Fig.* 140.

FIG. 141.



Parachute.

Parachute.—This term from the French, means "*guard against falling.*" It is an immense umbrella with cords attached to the sticks, *Fig.* 141, which on being detached from the balloon, opens by the resistance of the atmosphere, and thus descends slowly, landing the aeronaut in safety on the earth.

This appendage to the balloon was invented to secure safety in case of any accident, by which the gas might escape, but the Frenchman Garnerin, did not wait for such accident, but cut the rope by which the parachute was suspended, by way of experiment, thus trusting his life to its spreading, at the height of 3,000 feet. He landed in safety, but no one but a Frenchman, not even a Yankee, would ever have made such an experiment.

Dimensions.—Balloons are made of various sizes, commonly from 15 or 20, to 30 feet or more. That made by the veteran aeronaut, Green, was 64 feet in diameter, when filled, holding 80,000 cubic feet of gas. When filled with hydrogen it was capable of supporting 40,000 pounds, while with coal gas, it would carry only about 6,000 pounds. (The specific levity of these gases are stated in another place.) The weight of the silk it contained was 80 pounds. The largest number of persons who have ascended in this balloon at the same time was eighteen.

Discoveries.—Scientific men had high expectations with respect to the discoveries which aerial voyagers would make, on scientific subjects, especially electricity, meteorology, composition of the atmosphere, and its heat and cold. But nothing of so great importance in physical science as was expected, has been realized from this source.

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560. How is the balloon constructed? What is a parachute, and what its use? What are the sizes of balloons? What is said of scientific discoveries made by means of the balloon?

BAROMETER.

561. *The barometer is an instrument which, by means of a column of mercury in a glass tube, shows, by its elevation and depression, the different degrees of atmospheric pressure.*

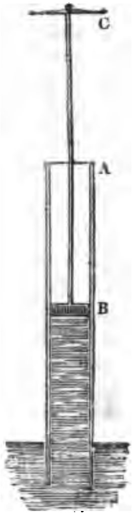
Suppose A, *Fig.* 142, to be a long tube, with the piston B, so nicely fitted to its inside, as to work air-tight. If the lower end of the tube be dipped into water, and the piston drawn up by pulling at the handle C, the water will follow the piston so closely, as to be in contact with its surface, and apparently to be drawn up by the piston, as though the whole was one solid body. If the tube be thirty-five feet long, the water will continue to follow the piston, until it comes to the height of about thirty-three feet, where it will stop.

562. If the piston be drawn up still further, the water will not follow it, but will remain stationary, the space from this height, between the piston and the water, being left a void space or vacuum.

563. The rising of the water in the above case, which only involves the principle of the common pump, is thought by some to be caused by *suction*, the piston *sucking* up the water as it is drawn upward. But according to the common notion attached to this term, there is no reason why the water should not continue to rise above the thirty-three feet, or why the power of suction should cease at that point, rather than at any other.

564. Without entering into any discussion on the absurd notions concerning this power, it is sufficient here to state, that it has long since been proved, that the elevation of the water, in the case above described, depends entirely on the weight and pressure of the atmosphere on that portion of the fluid which is on the outside of the tube. Hence, when the piston is drawn up under circumstances where the air can not act on the water around the tube, or pump-barrel, no elevation of the fluid will follow.

FIG. 142.



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561. What is the barometer? 562. Suppose the tube, Fig. 142, to stand with its lower end in the water, and the piston A to be drawn upward thirty-five feet, how far will the water follow the piston? 563. What will remain in the tube between the piston and the water, after the piston rises higher than thirty-three feet? 564. What is commonly supposed to make the water rise in such cases? Is there any reason why the suction should cease at thirty-three feet? What is the true cause of the elevation of the water, when the piston, Fig. 142, is drawn up?

565. If an atmospheric pump, or even the suction-hose of a fire engine, be inserted into the side of a tight cask filled with fluid, all the force of what is called suction may be exerted by the pump or engine in vain; for the liquid will not rise until an aperture, admitting the atmosphere, is made in some part of the cask. It may be objected that wells, though covered several feet deep with earth, still admit water to be drawn from them by pumps, with all the facility of those which are open. But it must be remembered that the ground is porous, admitting the atmosphere to an unknown depth from the surface, and hence wells can not be covered by any common means so as to exclude sufficient atmospheric pressure for the purpose in question.

566. *Conclusion.* It follows as a certain conclusion from what is above stated (563) as well as from the experiment made with *Fig.* 142, and all other experiments made by philosophers on this subject, that when a tube has its lower end placed in the water and the air from within removed by drawing up the piston, that it is the pressure of the atmosphere on the water around the tube which forces the fluid up to fill the space thus left by the removal of the air.

567. *Pressure of the atmosphere equal to* 33 *feet of water.*—It follows that the weight, or pressure of the atmosphere, is equal to the weight of a perpendicular column of water 33 feet high, for it is found (*Fig.* 142) that the pressure of the atmosphere will not raise the water more than 33 feet, though a perfect vacuum be formed to any height above this point.

Experiments on other fluids, prove that this is the weight of the atmosphere, for if the end of the tube be dipped in any fluid, and the air be removed from the tube, above the fluid, it will rise to a greater or less height than water, in proportion as its specific gravity is less, or greater than that fluid.

568. *Mercury or quicksilver*, has a specific gravity of about 13½ times greater than that of water, and mercury is found to rise about 29 inches in a tube under the same circumstances that water rises 33 feet. Now, 33 feet is 396 inches, which being divided by 29, gives nearly 13½, so that mercury being 13½ times heavier than water, the water will rise under the same pressure 13½ times higher than the mercury.

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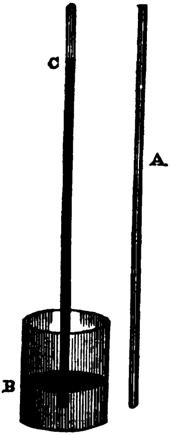
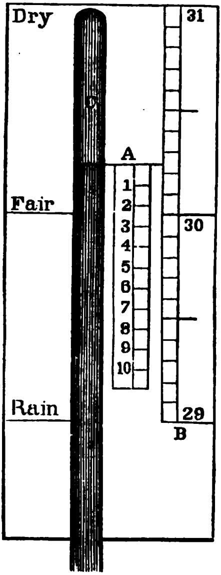
565. Will the suction-hose of a fire-engine raise water from a tight cask? 566. What is said to be the conclusion from the above stated experiments? 568. How is it proved that the pressure of the atmosphere is equal to the weight of a column of water 33 feet high? How do experiments on other fluids show that the pressure of the atmosphere is equal to the weight of a column of water 33 feet high? 568. How high does mercury rise in an exhausted tube? How does the height of mercury in the barometer indicate that of water?

FIG. 143.



Barometer.

FIG. 144.



Barometer Scale.

569. CONSTRUCTION OF THE BAROMETER.—The *barometer* is constructed on the principle of atmospheric pressure. This term is compounded of two Greek words, *baros*, weight, and *metron*, measure, the instrument being designed to measure the weight of the atmosphere.

Its construction is simple and easily understood, being merely a tube of glass, nearly filled with mercury, with its lower end placed in a dish of the same fluid, and the upper end furnished with a scale, to measure the height of the mercury.

570. Let A, *Fig.* 143, be such a tube, thirty-four or thirty-five inches long, closed at one end, and open at the other. To fill the tube, set it upright, and pour the mercury in at the open end, and when it is entirely full, place the forefinger forcibly on this end, and then plunge the tube and finger under the surface of the mercury, before prepared in the cup, B. Then withdraw the finger, taking care that in

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569. What is the principle on which the barometer is constructed? 570. Describe the construction of the barometer, as represented by Fig. 143.

doing this, the end of the tube is not raised above the mercury in the cup. When the finger is removed, the mercury will descend four or five inches, and after several vibrations, up and down, will rest at an elevation of 29 or 30 inches above the surface of that in the cup, as at C.

571. *Barometer Scale.*—This visible portion of the barometer is shown by *Fig.* 144, of which B is the principal scale, A the Vernier scale, and C the glass tube containing the mercury. In the principle scale an inch is divided into ten parts, but the divisions of the Vernier are equal to eleven of those of the principal scale, so that the divisions of this are each one hundredth of an inch larger than those of the barometer. The Vernier slides up and down and placing its upper end exactly at the level of the mercury, and comparing its divisions with those of the barometer, its height is indicated to within the hundredth part of an inch. The barometer is inclosed in a mahogany, or brass case for the convenience of carriage. The words Rain, Fair, and Dry, are indicated by the height of the mercury. The term *Vernier* is the name of the inventor of this part of the barometer.

572. *Cup of the Portable Barometer.*—The cup of the portable barometer differs from that described, (570,) for were the mercury inclosed on all sides, in a cup of wood, or brass, the air would be prevented from acting upon it, and therefore the instrument would be useless. To remedy this defect, and still have the mercury perfectly inclosed, the bottom of the cup is made of leather, which, being elastic, the pressure of the atmosphere acts upon the mercury in the same manner as though it was not inclosed at all.

573. Below the leather bottom, there is a round plate of metal, an inch in diameter, which is fixed on the top of a screw, so that when the instrument is to be transported, by elevating this piece of metal, the mercury is thrown up to the top of the tube, and thus kept from playing backward and forward, when the barometer is in motion.

574. Wheel Barometer.—In the common barometer, the rise and fall of the mercury is indicated by a scale of inches, and tenths of inches, fixed behind the tube; but it has been found that very slight variations in the density of the atmosphere are not readily perceived by this method. It being,

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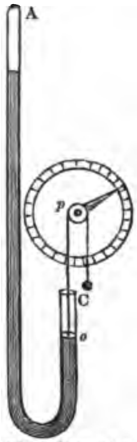
571. Describe the use of the Vernier. **572.** How is the cup of the portable barometer made so as to retain the mercury, and still allow the air to press upon it? **572.** What is the use of the metallic plate and screw, under the bottom of the cup? **574.** In the common barometer, how is the rise and fall of the mercury indicated? Why was the wheel barometer invented?

however, desirable that these minute changes should be rendered more obvious, a contrivance for increasing the scale, called the *wheel* barometer, was invented.

FIG. 145.



Wheel Barometer.

575. The whole length of the tube of the wheel barometer, *Fig.* 145, from C to A, is 34 or 35 inches, and it is filled with mercury, as usual. The mercury rises in the short leg to the point *o*, where there is a small piece of glass floating on its surface, to which there is attached a silk string, passing over the pulley *p*. To the axis of the pulley is fixed an index, or hand, and behind this is a graduated circle, as seen in the figure. It is obvious, that a very slight variation in the height of the mercury at *o*, will be indicated by a considerable motion of the index, and thus changes in the weight of the atmosphere, hardly perceptible by the common barometer, will become quite apparent by this.

576. *Heights Measured by the Barometer.*—The mercury in the barometer tube being sustained by the pressure of the atmosphere, and its medium altitude at the surface of the earth being 29 to 30 inches, it might be expected that if the instrument was carried to a height from the earth's surface, the mercury would suffer a proportionate fall, because the pressure must be less at a distance from the earth, than at its surface, and experiment proves this to be the case. When, therefore, this instrument is elevated to any considerable height, the descent of the mercury becomes perceptible. Even when it is carried to the top of a hill, or high tower, there is a sensible depression of the fluid, so that the barometer is employed to measure the height of mountains and the elevation to which balloons ascend from the surface of the earth. On the top of Mont Blanc, which is about 16,000 feet above the level of the sea, the medium elevation of the mercury in the tube is only 14 inches, while on the surface of the earth, as above stated, it is 29 to 30 inches.

577. *Diminution of Density.*—The following table shows at

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575. Explain Fig. 145, and describe the construction of the wheel barometer. **576.** What is stated to be the medium range of the barometer at the surface of the earth? Suppose the instrument is elevated from the earth, what is the effect on the mercury? How does the barometer indicate the height of mountains? **577.** Explain by the table the correspondence between the height, the fall of the mercury, and the temperature.

what rate the atmosphere decreases in density, as indicated by the barometer. A part of these numbers are from actual observations made from ascents in balloons, and a part from estimates. The medium pressure of the atmosphere, at the level of the sea, is estimated at 30 inches, and is expressed by 0.

Height in Miles.	Pressure.	Temperature.
	Inches.	Fahr.
0....	....30.00....	.....50.0
1....	....24.61....	.....35.0
2....	....20.07....	.....19.5
3....	....16.35....	......3.4
4....	....13.06....	.....13.3
5....	....10.41....	.....30.6
10....	.... 2.81....	....125.4
15....	.... .45....	....240.6

Thus, according to this estimate, at the height of fifteen miles, the mercury falls to less than half an inch, while the cold is equal to 240 degrees below the zero of Fahrenheit.

578. *Principles of the Barometer applied to the Water Pump.*—As the efficacy of the pump depends on the pressure of the atmosphere, the barometer will always indicate the height to which it can be effectual at any given place. Thus, on Mont Blanc, where the barometer stands at only 14 inches being less than one-half its height on the sea level, the water pump would only raise the fluid about 15 feet. Hence, engineers and others, who visit elevated countries, should calculate by the barometer, from what depth they can raise water by aerial pressure, before they erect works for this purpose.

At the city of Mexico and at Quito, for instance, the suction tube can only act to the depth of 22 or 20 feet, while on the Himalaya mountains its rise will be only about 8 or 10 feet.

579. *Heights Measured by the Temperature of Water.*—At the surface of the earth, water boils at the temperature of 212°, the barometer being at 30 inches, this being, as above stated, the medium pressure of the atmosphere. If the pressure happens to be a little more, or less, than this, as is sometimes the case, the boiling point may vary a few degrees from 212.

580. Now the pressure, as well as the temperature varies in a regular proportion as we ascend from the surface of the earth, as seen by the above table, and experiment shows that the boil-

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579. What is the heat of boiling water at the level of the earth? 580. Explain in hat manner the height of a mountain is found by boiling water?

ing heat of water, diminishes in as regular a gradation according to the pressure. Thus in a vacuum, water boils at about 60 or 70 degrees instead of 212°, even the heat of the hand being sufficient for this purpose. At Quito, which is nearly 9,000 feet above the sea, level water boils 194°—an egg therefore, cannot there, be boiled hard in an open vessel, and water will not rise in a suction pump above 20 or 22 feet. On this principle a traveler may find his elevation by means of boiling water, and a thermometer.

581. USE AS A WEATHER GLASS.—While the barometer stands in the same place, near the level of the sea, the mercury seldom or never falls below 28 inches, or rises above 31 inches; its whole range, while stationary, being only about 3 inches.

582. These changes in the weight of the atmosphere, indicate corresponding changes in the weather, for it is found, by watching these variations in the height of the mercury, that when it falls, cloudy or falling weather ensues, and that when it rises, fine clear weather may be expected. During the time when the weather is damp and lowering, and the smoke of chimneys descends toward the ground, the mercury remains depressed, indicating that the weight of the atmosphere, during such weather, is less than it is when the sky is clear. This contradicts the common opinion, that the air is the heaviest when it contains the greatest quantity of fog and smoke, and that it is the uncommon weight of the atmosphere which presses these vapors toward the ground.

583. A little consideration will show, that in this case the popular belief is erroneous, for not only the barometer, but all the experiments we have detailed on the subject of specific gravity, tend to show that the lighter any fluid is, the deeper any substance of a given weight will sink in it. Common observation ought, therefore, to correct this error, for every body knows that a heavy body will sink in water, while a light one will swim, and by the same kind of reasoning ought to consider, that the particles of vapor would descend through a light atmosphere, while they would be pressed up into the higher regions by a heavier air.

584. *Indications of the Barometer.*—The following indications of the barometer with respect to the weather, may be depended on as correct, being tested by the observations of the author:—

I. In calm weather, when the wind, clouds, or sun, indicate approaching rain, the mercury in the barometer is low.

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583. By what analogy is it shown that the air is lightest when filled with vapor?
584. Mention the indications of the barometer concerning the weather

II. In serene, fine, settled weather, the mercury is high, and often remains so for days.

III. Before great winds, and during their continuance, from whatever quarter they come, the mercury sinks lowest, and especially if they come from the south.

IV. During the coldest, clear days, when a gentle wind from the north or west prevails, the mercury stands highest.

V. After great storms, when the mercury has been lowest, it rises most rapidly.

VI. It often requires considerable time for the mercury to gain its wonted elevation after a storm; and on the contrary, it sometimes rains without the usual corresponding change in its altitude.

VII. In general, whether there are any appearances of change in the horizon or not, we may prognosticate rain whenever the mercury sinks during fine weather.

VIII. When it rains with the mercury high, we may be sure that it will soon be fair.

585. USE AT SEA.—The principal use of the barometer, is on board of ships, where it is employed to indicate the approach of storms, and thus to give an opportunity of preparing accordingly; and it is found that the mercury suffers a most remarkable depression before the approach of violent winds, or hurricanes. The watchful captain, particularly in southern latitudes, is always attentive to this monitor, and when he observes the mercury to sink suddenly, takes his measures without delay to meet the tempest. During a violent storm, we have seen the wheel barometer sink a hundred degrees in a few hours.

586. *Preservation by the Barometer.*—But we can not illustrate the use of this instrument at sea better than to give the following extract from Dr. Arnot, who was himself present at the time. "It was," he says, "in a southern latitude. The sun had just set with a placid appearance, closing a beautiful afternoon, and the usual mirth of the evening watch proceeded, when the captain's orders came to prepare with all haste for a storm. The barometer had begun to fall with appalling rapidity. As yet, the oldest sailors had not perceived even a threatening in the sky, and were surprised at the extent and hurry of the preparations; but the required measures were not completed, when a more awful hurricane burst upon them than the most experienced had ever braved. Nothing could with-

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585. Of what use is the barometer on board of ships? When does the mercury suffer the most remarkable depression? 586. What remarkable instance is stated, where a ship seemed to be saved by the use of the barometer?

stand it; the sails, already furled, and closely bound to the yards, were riven into tatters; even the bare yards and masts were in a great measure disabled; and at one time the whole rigging had nearly fallen by the board. Such, for a few hours, was the mingled roar of the hurricane above, of the waves around, and the incessant peals of thunder, that no human voice could be heard, and amidst the general consternation, even the trumpet sounded in vain. On that awful night, but for a little tube of mercury which had given the warning, neither the strength of the noble ship, nor the skill and energies of her commander, could have saved one man to tell the tale."

CIRCULAR BAROMETER.

587. A barometer lately invented in France and patented both there and in England, is of a circular form, and about six inches in diameter. Instead of mercury, as in the common instrument, this consists of an exhausted, circular, flattish vessel, placed near the circumference, and on which the atmosphere acts, and by means of which, its pressure, through the medium of clock work, is indicated on a revolving index. This barometer is particularly designed for the use of travelers, and for ascertaining the elevation of mountains, for which purposes it is much more convenient than the common instrument, being of solid metal, and in form and size such as to make it both of safe and easy conveyance. Having seen this instrument only for a few moments, we can give no satisfactory description of its structure.

WATER PUMPS.

588. *The efficacy of the common pump in raising water, depends upon the force of atmospheric pressure, the principles of which have been fully illustrated under the articles, Air-Pump and Barometer.*

589. An experiment, of which few are ignorant, and which all can make, shows the principle of the pump in a very striking manner. If one end of a straw be dipped into a vessel of liquid, and the other end be sucked, the liquid will rise into the mouth, and may be swallowed; and what country lad has not had a drink of cider in this way?

The principles which this experiment involves are exactly the same as those concerned in raising water by the pump. The vessel of liquid answers to the well, the straw to the pump log, and the mouth acts as the piston, by which the air is removed.

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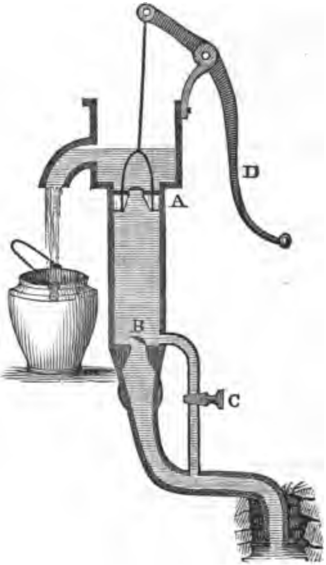
588. On what does the efficacy of the common pump depend? What experiment is stated, as illustrating the principle of the common pump? How many kinds of pumps are mentioned?

Water pumps are of three kinds, namely, the *sucking*, or *common* pump, the *lifting* pump, and the *forcing* pump.

590. COMMON METALLIC PUMP.—This (*Fig.* 146,) consists of a brass or iron barrel, A, containing at its upper part a hollow piston and valve, opening upward. Below this there is another valve, also opening upward. The pipe and stop-cock C, are for the purpose of letting the water from the barrel to the tube, which descends into the well.

The action of this pump depends on the pressure of the atmosphere, and will be readily understood by the pupil who has learned what is said under the articles *air-pump* and *barometer*.

FIG. 146.



Common Metallic Pump.

591. On raising the lever, D, the piston, A, descends down the barrel, the lower valve, B, at the same moment closing by the weight of the water, while the upper one opens and lets the water through. Then, on depressing the lever, the piston rises, its valve closing, and elevating the water above it. By this action a vacuum would be formed between the two valves, did not the lower one open and admit the water through the pipe above it. The lever again being worked, the same process is repeated, and the water is elevated to the spout in an interrupted stream.

The tube, with the stop-cock C, leading from the barrel to the pipe, is added for the purpose of letting the water escape from the former in cold weather, and thus prevent its freezing.

592. Although, in common language, this is called the suction pump, still it will be observed that the water is elevated by *suction*, or, in more philosophical terms, by atmospheric pres-

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590. Which kind is the common? Describe the common pump. Explain how the common pump acts. **591.** When the lever is raised, what takes place in the pump-barrel? When it is depressed, what takes place? **592.** How far is the water raised by atmospheric pressure, and how far by lifting.

sure, only above the valve A, after which, it is raised by *lifting* up to the spout. The water, therefore, is pressed into the pump-barrel by the atmosphere, and thrown out by the power of the lever.

593. Lifting Pump.—The *lifting-pump*, properly so called, has the piston in the lower-end of the barrel, and raises the water through the whole distance, by forcing it upward, without the agency of the atmosphere.

In the *suction-pump*, the pressure of the atmosphere will raise the water 33 or 34 feet, and no more, after which, it may be lifted to any height required.

FORCING—PUMP AND FIRE—ENGINE.

594. This engine may be of immense importance in cities, or in the vicinity of cotton or other factories. It is believed to be a recent invention. The following description is from Hogg's Natural Philosophy: London, 1853.

A well, A, is provided with a pump-barrel, B B, in which works a piston; a valve, opening upward, being at C, and another, also opening upward in the air-vessel, D D, at E.

In the street, or at any other point, the ornamental portion, H, of the machine is placed above the ground, the other parts being in the well, as shown by the cut. In this, the piston rod, K K, works, being moved by the handle, M. A pipe, F F, proceeds from the air-vessel, and is terminated by a screw junction, to which the hose, G, is attached, when required.

It operates thus: On the lever, M, being depressed, the piston is raised, creating a vacuum, into which the water presses through the valve C. The handle being raised, the piston is depressed, by which the valve C is closed, and the water forced through the pipe into the air-vessel, through the valve E. By the pressure of the air in this vessel, the water is forced from it, through the pipe F, to the hose G, when required to extinguish a fire; at other times, it delivers its water like a common forcing-pump. By compression of the air in the vessel, D D, by the force of the piston, it is said that this machine, of only moderate size, will throw the water with such force as to extinguish fires at the height of 60 feet.

595. Atmospheric and Forcing-Pump.—A curious combination of the atmospheric and forcing-pumps, is the following *Fig.* 148.

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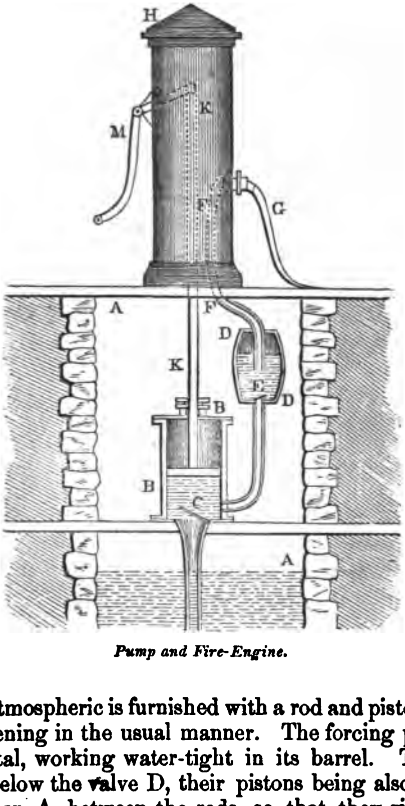
593. How does the lifting-pump differ from the common pump? **595.** Explain Fig. 147, and show in what manner the water is brought up through the pipe C, and afterward thrown out at the pipe G.

FIG. 147.



Pump and Fire-Engine.

596. The atmospheric is furnished with a rod and piston, with the valve, C, opening in the usual manner. The forcing piston, B, is of solid metal, working water-tight in its barrel. The barrels are joined below the valve D, their pistons being also connected by a cross-bar, A, between the rods, so that they rise and fall together.

Now, when the lever is depressed, and the pistons raised, the water above the valve C is discharged at the spout in the manner of the common suction-pump, and the space is filled by atmospheric pressure through the lower valve D, by the suction-pipe. When the pistons descend, this valve closes, and the solid piston, B, drives the water through the valve C, and

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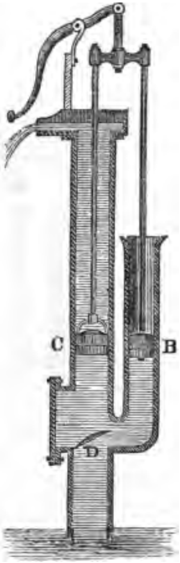
596. What is the difference between the pump, Fig. 147, and the common atmospheric and forcing-pump?

above that piston and to the spout. Thus, one piston operates when the lever rises, and the other when it falls, producing in effect a constant stream of water from the spout.

In the construction of this pump, it should be considered that as both cylinders are filled at the same time, the suction pipe ought to be large in proportion.

FIG. 148.

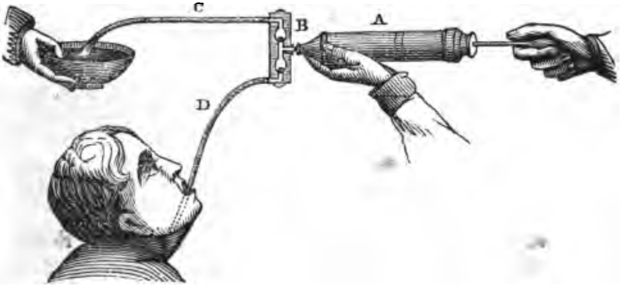


Atmospheric and Forcing Pump.

597. Stomach–Pump.—The design of this pump, of which there are several varieties, is to throw a fluid into the stomach, and again withdraw it, without changing the apparatus, but only its *position.* In cases of poisoning, the contents of the stomach may thus be diluted and withdrawn, including the deleterious matter, and thus the life of the individual be saved.

598. That here described is from the Journal of the Franklin Institute. It consists of a common metallic syringe, A, *Fig.* 149, screwed to a cylindrical valve-box, B, which contains two ovoid cavities, in each of which there is a loose spherical metallic valve. The ends of the cavities are pierced, and the valves fit exactly either of the orifices. Thus, it makes no difference which end of the valve-box is upturned, the valve falling down

FIG. 149.



Stomach Pump.

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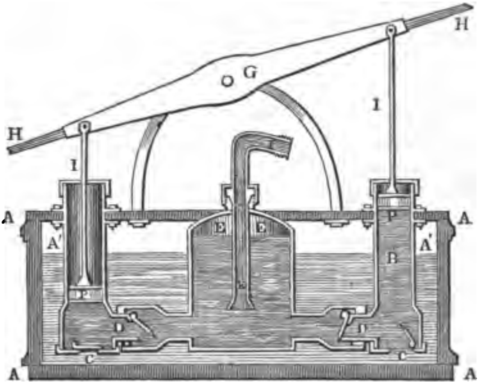
597. What is the use of the stomach-pump? **598.** Describe the stomach-pump, and show the reason why it acts in opposite ways on being turned over.

FIG. 150.



Fire-Engine.

and closing the orifices in either direction. The flexible India rubber tubes, C D, are attached to the opposite ends of the cavities.

Now, suppose the then upper tube is introduced into the stomach, and the lower one into a basin of warm water; in this position, on working the syringe, the liquid would be injected into the stomach, and the poison diluted; then, on reversing the position, by turning the syringe in the hand, without withdrawing the tube from the stomach, the valves drop on the other orifices, and the water is pumped from the stomach into the basin, as represented by the figure.

This is an interesting and beautiful invention, and, no doubt, has been the instrument of saving many human lives in cases of poisoning.

599. Fire-Engine.—This important machine is represented by *Fig.* 150, and is thus described: Two forcing pumps, B, are placed in the cistern of water A A. In the barrels are the pistons P P, attached, by the rods I I, to the working-beam G, which is moved by the handles H H. The valves C C open inwards to the barrels, and, D D open to the receiver, E E.

Action.—On working the beam, the pistons alternately play up and down, by which the water is projected in a continued

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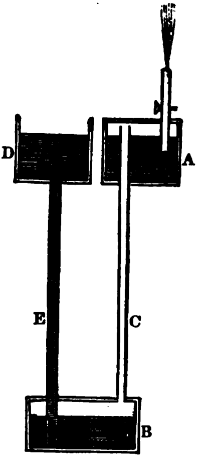
599. Explain Fig. 150, and describe the action of the fire-engine. What causes the continued stream from the direction pipe of this engine?

stream into the receiver, which contains air, at E E. By the action of the pumps, the water is pressed from the receiver through the pipe K, and, by the reaction of the air, the stream is continued, without the least interruption, and is directed to any place required, by the hose which is screwed on the pipe at F. The valves, it will be seen, all open inwards, thus preventing the escape of the water, either from the air-box or the cistern. This engine is simply two forcing pumps, with their forces combined.

FIG. 151.

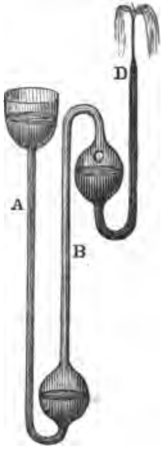


Hiero's Fountain.

600. Fountain of Hiero.—There is a beautiful fountain, called the *fountain of Hiero*, which acts by the elasticity of the air, and on the principle of hydrostatic pressure. Its construction will be understood by *Fig.* 151, but its form may be varied according to the dictates of fancy or taste. The boxes A and B, together with the two tubes, are made air-tight, and strong, in proportion to the height it is desired the fountain should play.

To prepare the fountain for action, fill the box A, through the spouting tube nearly full of water. The tube C, reaching nearly to the top of the box, will prevent the water from passing downward, while the spouting pipe will prevent the air from escaping upward, after the vessel is about half filled with water. Next, shut the stop-cock of the spouting pipe, and pour water into the open vessel D. This will descend into the vessel B, through the tube E, which nearly reaches its bottom, so that after a few inches of water are poured in no air can escape, except by the tube C, up into the vessel A. The air will then be com-

FIG. 152.



Hiero's Fountain.

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600. How is the fountain of Hiero constructed? On what will the height of the jet from Hiero's fountain depend?

pressed by the weight of the column of water in the tube C, and therefore the force of the water from the jet-pipe will be in proportion to the height of this tube. If the tube is 20 or 30 feet high, on turning the stop-cock, a jet of water will spout from the pipe that will amuse, and astonish those who have never before seen such an experiment.

Fig. 152, is another form of Hiero's Fountain, made of glass, so as to observe the action of the water. It requires a frame for its support, not shown in the figure. The description of *Fig.* 151, will answer for this.

CHAPTER VIII.

HEAT, AND THE LAWS OF ITS ACTION.

601. *In respect to the laws of incidence and reflection, and in many other respects, the phenomena of light and heat are the same. But in respect to transmission, radiation, distribution, effects on other substances, both chemical and mechanical, and the manner in which it affects our senses, there are, it is well known, great differences.*

DISTRIBUTION OF HEAT.

602. The rays of heat falling on a body are disposed of in three ways. First, they may be *reflected*, or rebound from the surface; second, they may be *absorbed* or received into the substance of the body; or third, they may be *transmitted*, or pass through its substance.

603. *Reflection.*—Radiant heat, that is, the heat flowing from any hot body, is like light reflected from polished surfaces, and as in light, the angle of reflection is equal to that of incidence. Those surfaces, however, which reflect light most perfectly, are not always the best reflectors of heat. Thus, polished metals are the best reflectors of heat, while glass, which reflects light most perfectly, is a very imperfect reflector of heat; thus tin plate reflects about eight times as much heat as a glass mirror.

604. *Absorption.*—Radiant heat is *absorbed* with very different facilities by bodies and surfaces of different kinds. Those

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601. In what respects are action of heat and light the same? In what respects are their phenomena dissimilar? 602. In what ways are the rays of light diffused? 603. What is meant by reflection of heat? 604. What by absorption.

surfaces which *radiate* most readily, *absorb* heat with the greatest facility, and on the contrary, those surfaces which radiate feebly, do not readily absorb heat. Thus a plate of tin, if painted black, will both absorb, and radiate perfectly; while, if the surface retains its bright metallic polish, it will neither absorb nor radiate. Hold the black surface near the fire, and the metal will soon become too hot for the fingers; while the bright surface will not become even warm, by the same exposure. There is also a difference between culinary heat and that of the sun, with respect to absorption, for if a piece of plate glass be held before the fire it soon becomes hot, while every window shows by the temperature of the glass, that it does not absorb the heat of the sun.

605. *Transmission.*—Most transparent substances transmit heat, that is, allow it to pass through their pores, with more or less facility; in this respect, however, experiment proves that there are great differences in bodies, where from external appearance, little or none might be expected. Thus, rock-crystal transmits heat very perfectly, while alum, though equally transparent, admits few of the calorific rays to pass through it. This difference is so great, that a piece of smoky, brown rock-crystal, which was fifty-eight times thicker than a transparent plate of alum, transmitted 19 rays, while the alum transmitted only 6. The cause of this remarkable difference is unknown, though probably it depends on the crystaline structure of the two substances.

606. *Operation of these Laws.*—The general diffusion of heat seems to depend on the operation of the above described natural laws, and hence it is, that in the same vicinity, two thermometers graduated alike, and equally exposed, always indicate the same temperature.

607. Other Effects of Heat.—Besides the above, we will illustrate and explain two other effects of heat viz,: Expansion and Circulation.

608. *Expansion.*—The operation of the thermometer depends on the expansion of the mercury by heat; but the apparatus, *Fig.* 153, is designed to show the expansion of the solid metals, by the same power. This instrument is called the *Pyrometer*, and is thus described. A, is a rod of metal laid on the rests, and one end of which is made to touch the screw, B, while the other end presses on the lever, C, which acts on the index, E,

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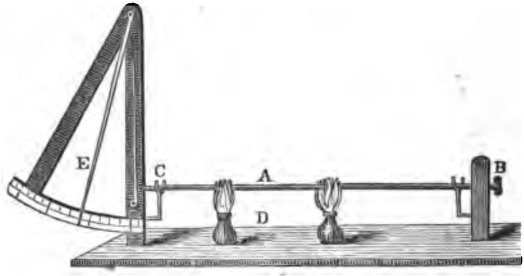
What by radiation? What surfaces reflect heat best? Give examples. What surfaces possess the greatest absorbing powers? Examples. 605. Give examples of the transmission of heat through substances. 606. What are the means of the general diffusion of heat? 608. On what does the operation of the thermometer depend?

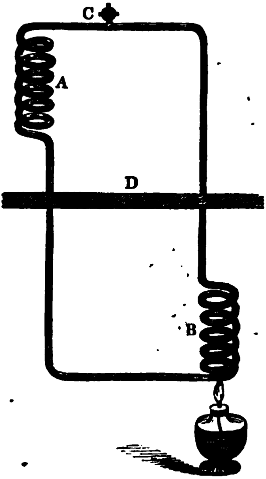
so that it will be seen that a slight expansion of the metal will be apparent by this double action. On the platform D, are lamps, by the heat of which the metals are expanded. This pyrometer is of brass. In making experiments, the different metals should be of the same size and length, and the heat of the lamps applied the same length of time.

FIG. 153.



Pyrometer.

FIG. 154.



Circulation by Heat.

In general it is found by this instrument, that the metals most easily fusible, expand most by the same increments of heat. Thus tin, lead, and zinc, expand more than copper, silver, gold, platina, or iron.

609 CIRCULATION.—Let the endless iron tube, *Fig.* 154, be filled full of water, and heat applied to the spiral portion of it at B. The fluid, by the influence of the heat, will instantly begin to circulate through the tube, the warmed portion rising upward, while the cold in the opposite portion of the tube will descend to take its place, until the whole becomes equally heated. The tube may be led to an apartment above the floor, D, where the other spiral at A, is designed to

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Describe the pyrometer What is said of the fusibility of different metals? 609 Describe the apparatus, Fig. 154, and effects of heat on the water.

diffuse the heat, in proportion to the extent of the metallic surface exposed.

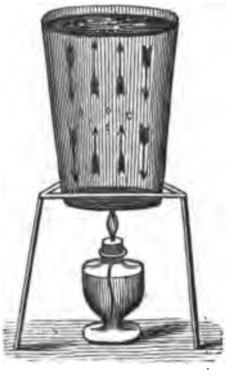
The water in such tubes is heated to much above the boiling point in the open air. The use of such tubes for heating apartments is becoming quite common; and it is said that after every attention to make the apparatus steam tight, still the water escapes, requiring a small addition once in a few weeks, which is introduced by the stop-cock, C.

THERMOMETER.

610. *Did not the heat diffuse itself as above described,* (606,) *the thermometer would be entirely useless, since several in the same vicinity, though graduated exactly alike, would indicate different temperatures.*

611. CHANGE OF PARTICLES BY HEAT.—Count Rumford thought that any change in the temperature of fluids, could only be effected by a change in the place of their particles; and any one who will watch boiling water in a glass vessel, will see the grounds of this opinion, especially if it contains particles of some solid of near its own specific gravity.

FIG. 155.



Motion of particles by Heat

The glass jar of water placed over a lamp *Fig.* 155, will soon begin to show the circulation of the fluid. The portion near the bottom, as it becomes dilated by the heat, will become lighter than that near the sides and will rise towards the surface, as shown by the arrows, while that near the sides will fall down to take its place, because it is colder, so that the circulation will continue until all is of the same temperature.

612. The term *thermometer* comes from two Greek words, signifying *heat measurer;* and its use strictly corresponds to the name, being an instrument for comparing the degrees of free heat existing in other bodies. This it does by the expansion and contraction of a fine thread of mercury, confined in a glass

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610. Explain Fig. 155. Why do the particles rise near the lamp, and fall at the sides of the vessel? 611. What is said of the use of the thermometer without an equal diffusion of heat? 612. What does *thermometer* mean?

tube, having a small reservoir of the same metal at the lower end, called the bulb.

613. Mercury is employed for this purpose for several reasons; one is that fluids, as alcohol, occupy too much space; another, that this metal is more uniform in expanding and contracting than any other substance; and lastly, it is not liable to vaporize in the vacuum in which it is placed, and thus, like liquids, to interfere with its own variation in the stem.

614. ALCOHOLIC THERMOMETER.—Although mercury, or quicksilver, is the best substance known for the construction of thermometers, and is that universally employed in temperate climates, yet it is objectionable in extreme, or polar latitudes, on account of its liability to freeze. In Siberia, and other northern inhabited regions, where the cold is often down to —40° of Fahrenheit's scale, alcoholic thermometers are of necessity employed, since at that point mercury becomes solid by freezing, and therefore useless. These thermometer tubes are much longer than ordinary, since alcohol expands in a greater proportion than mercury by the same increment of heat.

615. *Different Mercurial Thermometers.*—There are three thermometers in general use, namely, *Fahrenheit's* which is used in England, and in this country; the *Centigrade*, constructed by Celsius, which is generally used in France; and *Reaumur's* thermometer, adopted in Germany.

616. *Fahrenheit*, (*Fah.*)—In this the intermediate space between the freezing and boiling points is divided into 180 degrees; the freezing being marked 32°, and the boiling 212°. This scale was invented by Fahrenheit, from an erroneous belief that 32 of these divisions below the freezing point of water, which is therefore 0 on the scale, indicated the *zero*, or greatest degree of cold. But he afterward discovered his error, and his instrument being in use, corrected it as far as possible, by adding a series of descending degrees below his zero, prefixing to them the sign —, or minus, that is, below zero.

617. *Centigrade*, (*Cent.*)—It is also sometimes indicated by *Cel*, for the name of the inventor. It consists of an arrangement of the scale, in which the freezing point is marked 0, or *zero*, and the boiling point is marked 100°. This is a more convenient scale than the other, the freezing and boiling points being even numbers, and all below the former — minus.

618. *Reaumur*, (*Reau.*)—In this the freezing point, as in

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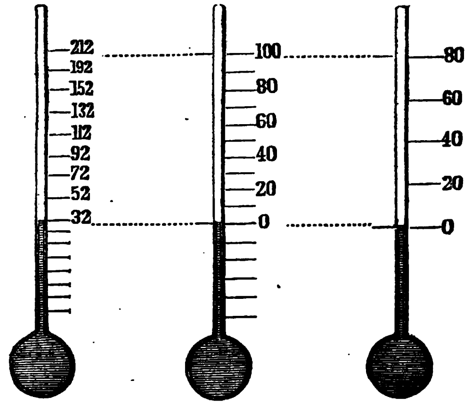
613. Why is mercury used in thermometers in preference to liquids? 614. Why are alcoholic thermometers used? 615. What are the names of the murcurial thermometers? 616. What are the divisions of Fahrenheit's scale? 617. What are those of the Centigrade? 618. What are those of Reaumur?

the last, is marked 0, while the boiling point, instead of being 100°, is marked 80°. The degrees are continued both above and below these points, those below being negative or minus, as in the others.

These Thermometers Compared.—In books of foreign travels, where the author adopts the thermometer of the country he describes, the reader is often perplexed to know what degrees of temperature are indicated according to his own scale, by what he reads. Figures are therefore added of each, *Fig.* 156, together with a table showing the correspondence of the three, and the rules for converting one scale into the others.

FIG. 156.



Fahrenheit. *Centigrade.* *Reaumur.*

619. Thus the Centigrade scale is reduced to that of Fahrenheit, by multiplying by 9 and dividing by 5, and that of Reaumur to that of Fahrenheit, by multiplying by 9 and dividing by 4; or that of Fahrenheit to either of the others by reversing these processes. Examples:—

Cent. 100° × 9 = 900 ÷ 5 = 180 + 32 = 212° Fah.
Reau. 80° × 9 = 720 ÷ 4 = 180 + 32 = 212° Fah.
Fah. 212° − 32 = 180 × 5 = 900 ÷ 9 = 100° Cent.
Fah. 212° − 32 = 180 × 4 = 720 ÷ 9 = 80° Reau.

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619. How is the Centigrade reduced to that of Fahrenheit? How is that of Reaumur reduced to that of Fahrenheit?

The following Table from Prof. Hoblyn's Dictionary of Science, shows at a single view the correspondence between these thermometers, from the zero to the boiling point of Fahrenheit.

	Fahrenheit.	Centigrade.	Reaumur.
BOILING.	212	100	80
	200	93.33	74.66
	190	87.77	70.22
	180	82.22	65.77
	170	76.66	61.33
	160	71.11	56.88
	150	65.55	52.33
	140	60	48
	130	55.55	33.55
	120	48.88	39.11
	110	43.33	34.66
	100	37.77	30.22
	90	32.22	25.77
	80	26.66	21.33
	70	21.11	16.88
	60	15.55	12.44
	50	10	8
	40	4.44	3.35
FREEZING.	32	0	0
	20	6.66	5.33
	10	12.22	9.77
ZERO.	0	17.77	14.22

SELF-REGISTERING THERMOMETER.

620. Several methods, of making thermometers mark their own temperatures, in such a manner as to leave permanent indications of the highest and lowest points, have been invented. It is easy to see, that in attempting to find the temperature of the deep ocean, by the common thermometer, the object would be defeated by the change in the height of the mercury as the instrument is drawn toward the surface. If, however, a mark could be fixed at the point where the mercury was lowest when thousands of feet under the surface, then the object in question would be attained, and many other questions with respect to the changes of temperature during night, or day, when it would be inconvenient to watch the instrument, would be solved, and such are the objects of this instrument.

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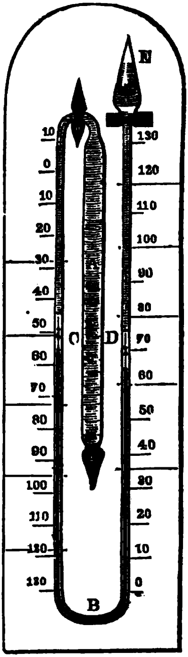
620. What are the uses of self-registering thermometers?

621. **Six's Thermometer.**—Among inventions for the above purpose, Six's *self-register* is the best. It consists of a single tube, twice bent *Fig.* 157, and having a long, cylindrical bulb A, filled with alcohol which reaches down the small tube to C, where it rests on mercury, the latter extending down to B, and up to D. Above this it is again filled with alcohol so that the lower parts of the tube are filled with a heavy, and the upper, with a light fluid.

FIG. 157.

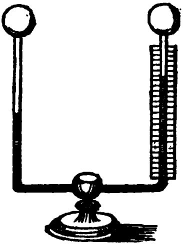


Self-Registering Thermometer.

On each side, and in contact with the mercury, is placed a little iron index, C, and D, to which are fixed by cement, a hair which, pressing against the side of the tube fixes the index in any place unless forcibly moved by the expansion of the mercury. These iron indexes are placed in contact with the mercury, by means of a magnet carried along the outside of the tube. Being lighter than the mercury they float on, but do not sink in it, and are there covered by the alcohol.

622. **Action.**—When the alcohol in the large bulb A, expands, it drives the mercury up the opposite tube, say to D, where, on its contraction the index is left. On the contrary, if the cold contracts the alcohol, the opposite index C, rises, and in the like manner, is left at the point of the greatest contraction, when the alcohol again expands. So that by this curious contrivance, the highest, and lowest degrees of heat are indicated, to which it has at any time been exposed, and which may be known, weeks or months afterwards.

FIG 158.



Differential Thermometer.

623. **Differential Thermometer.**—This instrument is shown by *Fig.* 158. It consists of two thin glass bulbs of an

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621. How is Six's thermometer for this purpose constructed? Describe the action of this thermometer. 623. What is the construction of the differential thermometer?

inch in diameter, connected by a glass tube bent at right angles, as the figure shows. This tube is partly filled with colored alcohol. Now when one of the bulbs is heated more than the other, the air in it expands, and drives the liquid into the other bulb.

624. It does not, therefore, indicate the temperature of the atmosphere, as the same degree of heat on both bulbs at the same time produces no change, its design being merely to show the *difference* of temperature to which the bulbs are exposed.

CONSTRUCTION OF THERMOMETERS.

625. Having blown the bulb, it is filled with mercury, as follows: The bulb is gradually heated over an alcohol lamp, which expels most of the air, the small end being open. This end is then dipped into a vessel of mercury, which as the bulb cools, ascends up the tube, which on being inverted the metal descends into the bulb. The bulb is next heated until the metal boils, which excluding the air entirely, the tube is *regulated* with respect to the height of the mercury, and then closed, or hermetrically sealed.

626. GRADUATION.—This consists in making two fixed points on the tube, which, being marked with a diamond or file, the intervening space is then divided into equal parts. These are the *freezing* and *boiling* points. To determine the former, the tube is placed in a vessel, filled with pounded ice, and allowed to remain there until it acquires the temperature of the ice. The point for Fahrenheit, thus indicated is marked 32° (*Fig.* 159.)

627. *Boiling.*—The boiling point is determined by placing the tube in a vessel with a long neck, the steam escaping from the two short tubes, on each side, so that the place of marking may not be obscured. When the water has boiled by means of the alcohol lamp for a while, the point where the mercury stands is marked, which being the boiling point, is of course 212°.

Remarks.—While the steam is allowed to escape, no boiling heat, however, protracted will raise the mercury above this height. The reason is, that the steam carries off the heat, the vapor increasing in proportion to the heat of the fire, so that no accumulation occurs so long as the vessel is open. Nor will the pounded ice sink the mercury below 32°, however long applied, provided the melted ice, or water be allowed to escape.

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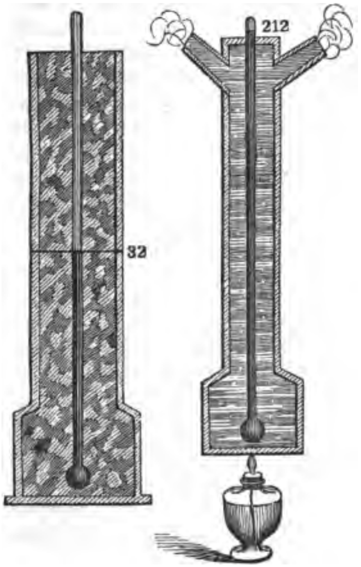
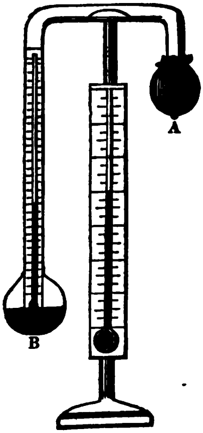
624. What is the use of this instrument? 625. How is the thermometer tube fitted? 626. How is the freezing point found? 627. How is the boiling point found?

FIG. 159.



Construction of Thermometers

FIG. 160.



Hygrometer.

HYGROMETER.

628. The name of this instrument from the Greek, signifies "moisture measurer." Its use is, to show the state of moisture in the atmosphere. Many inventions for this purpose have been tried, but that represented by *Fig.* 160, is at present considered the best.

It is called *Daniel's dew-point hygrometer.* It consists of two balls, connected together by a bent tube, as shown by the figure, the whole being of glass. The ball B, contains a small quantity of ether, by the boiling of which, the air has been expelled from the tube. In it a small thermometer is placed, with its bulb in the ball. The lower part of this ball is gilded, that the deposited dew may be visible. The other ball, A, is covered with muslin, and is kept moist with ether, the evaporation of which

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628. What is the meaning of the term hygrometer? What is that here described called? Explain its principle, and the manner of using it.

produces cold, which gradually, by the evaporation of the ether in the other ball, reduces the temperature in that to the dew-point, which is indicated by the deposition of moisture on the gilded ball.

The degree of temperature at which this deposition takes place, is shown by the thermometer in the tube, and this degree is called the *dew-point*, and this is effected at a higher or lower degree, according to the moisture in the atmosphere. The thermometer on the stem indicates the temperature of the air at the time when the observations are made.

CHAPTER IX.

STEAM, AND THE STEAM-ENGINE.

ELASTIC FORCE OF STEAM.

629. Preparatory to a description of the Steam-Engine, it is proper to make some remarks and illustrations concerning the force exerted by steam itself, and to show the manner in which that force is ascertained. This is abridged from a recent London work, Grahams' Elements of Chemistry.

630. *Force of Steam.*—At temperatures above that at which steam is produced, or above 212° its elastic force is determined by heating water in a strong globular vessel of glass, containing mercury, M, and water, W, *Fig.* 161. This vessel has a long neck T, screwed to it, open at both ends, and dipping into the mercury, and to which is affixed a scale A, divided into inches. This vessel has also two other openings into one of which is screwed the stop-cock B, and into the other the thermometer L, having its bulb within the globe.

The water is boiled for some time, with the stop-cock open, and the steam escaping, the thermometer will remain at 212°, but on shutting the aperture, and thus confining the steam, the thermometer will begin to rise above 212°. The steam in the globe becoming more, and more dense by confinement, forces the mercury to ascend in the guage tube A, to a height proportioned to its elastic force. The height of the mercury in the tube shows the amount of pressure which the steam exerts,

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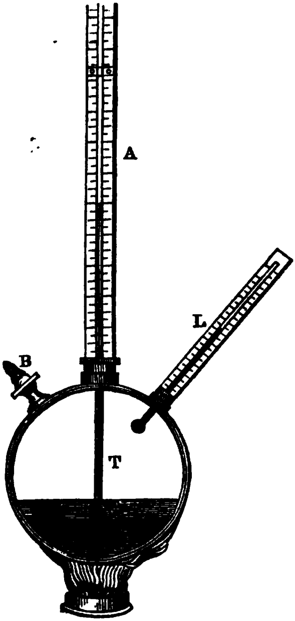
629. Explain Fig. 160, and show how the elastic force of steam is determined. 630 To what is the weight of the atmosphere equal.

while the thermometer indicates the temperature above 212°, at which any particular force is given.

631. The weight of the atmosphere itself is equivalent to 30 inches of the barometer, which pressure is overcome by the steam at 212°, before it began to act on the mercurial gauge, in consequence of confining the steam. For every 30 inches, the mercury is forced up in the tube by the steam, it is said to have the pressure of another atmosphere. Thus when the mercury in the tube stands at 30 inches, the steam has the weight of two atmospheres; at 45 inches two and a half atmospheres, and at 60 inches, three atmospheres, and so in this proportion.

FIG. 161.



Force of Steam.

NEWCOMEN'S ENGINE.

632. In this edition the description of Newcomen's engine, is omitted, as being superseded by the improvements of the present time, and therefore occupying room which we have replaced by the insertion of such items of new discoveries, as were thought of much higher importance. It will be seen in various parts of this revision, that no pains have been spared in abridging such articles as admitted it, in order to make room for many important Mechanical and Philosophical facts which have been discovered since our last revision.

633. **Watt's Steam-Engine.**—What is meant by the double action of Watt's engine consisted in the application of steam alternately on each side, or above and below the piston, and by which it was moved both up and down, while that of Newcomen's was moved only in one direction, that is, *up* by the steam, and *down* by the force of the atmosphere operating over a

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631. What is the force of the steam equal to when the gauge is at 60 inches.

vacuum. The importance of Watt's invention can only be appreciated when it is considered that all steam-engines at the present day are worked on this principle.

634. WATT'S DOUBLE-ACTING ENGINE.—In considering the applicability of the steam-engine to manufactures generally, it occurred to Watt that if he could contrive to *admit steam alternately above and below the piston, and, at the same time produce a vacuum alternately below and above the piston,* a double-acting cylinder would be produced, and an impulse thus be communicated by the ascent as well as by the descent of the piston, and a uniform *continuous action* be effected. It was desirable, also, to convert this reciprocating action into a circular one.

635. On this subject Watt observes: "Having made my single reciprocating engines very regular in their movements, I considered how to produce *rotative motions* from them in the best manner; and, among various schemes which were subjected to trial, or which passed through my mind, none appeared so likely to answer the purpose as the application of the *crank,* in the manner of the common turning lathe; but, as the rotative motion is produced in that machine by impulse given to the crank in the descent of the foot only, it requires to be continued in its ascent by the energy of the *wheel,* which acts as a *fly.*

636. "Being unwilling to load my engine with a fly-wheel heavy enough to continue the motion during the ascent of the piston (or with a fly-wheel heavy enough to equalize the motion, even if a counter-weight were employed to act during the ascent,) I proposed to employ two engines, acting upon two cranks fixed on the same axis, at an angle of 120° to one another, and a weight placed upon the circumference of the fly-wheel at the same angle to each of the cranks, by which means the motion might be rendered nearly equal, and only a very light fly-wheel would be requisite." In following out this plan, some very important changes were introduced into the machinery of the steam-engine: the principle of these are the double-acting cylinder, the parallel motion, the crank, the fly-wheel, and the governor. Each of these will first be severally described; and, their operation in the double-acting engine be afterward pointed out.

637. *Double-acting Cylinder.*—The first alteration to be noticed in the double acting engine is that of the cylinder. To insure its *double action,* it is necessary to provide, at each end of the cylinder, a means of *admission* of steam from the boiler,

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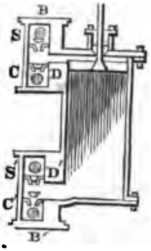
634. What was Watt's great improvement in the steam-engine? 637. What is meant by the double-acting cylinder?

and of *escape* for the steam to the condenser. Hence, the double action, which means that the piston is both raised and depressed by the force of steam.

638. For this purpose, a *steam-box* is fixed to each end of the cylinder, communicating, in the one case with the upper, in the other with the lower surface of the piston. In *Fig.* 162, B is the upper and B′ the lower steam-box. Each of these boxes is furnished with two valves.

FIG. 162.



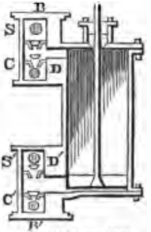
Double-acting Cylinder.

639. I. In the *upper steam-box*, the upper or *steam valve*, S, admits steam from the boiler through a tube, the mouth of which is seen immediately above the valve; the lower or *exhausting valve*, C, permits the escape of the steam from the cylinder to the condenser, through a tube opening immediately below the valve. In this figure, the piston is at the top of the cylinder; the exhausting valve is, therefore, represented as closed, and the steam valve as open, for the admission of steam, which rushes through the passage D to the top of the cylinder, in order to force the piston to the bottom.

640. II. In the *lower steam-box*, a corresponding mechanism is observed, and its valves must be worked at the same moment as those of the upper box, but upon an exactly opposite principle. The cylinder is full of steam, and the piston at the top; the *steam valve*, S′, must, therefore, be closed, and the *exhausting valve*, C′, opened, in order that the steam may rush out at the passage, D, and a vacuum be formed *beneath* the piston, to give effect to the steam which is now entering above it.

641. In *Fig.* 163, the piston is at the bottom of the cylinder. 1. In the *upper steam-box*, the *steam valve*, S, is accordingly closed, and the *exhausting valve*, C, opened, to admit of the escape of the steam from above the cylinder through the passage, D, into the condenser, and thus to produce a vacuum *above* the piston. 2. In the *lower steam-box*, the *exhausting valve*, C′, is closed, and the *steam valve*, S, opened, in order that steam may rush in by the passage, D′, and force the piston to the top of the cylinder.

FIG. 163.



Double-acting Cylinder.

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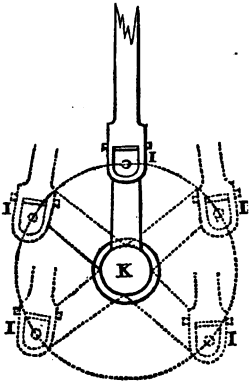
638. Explain the double-acting cylinder by Figs. 162 and 163.

From the preceding description, it is evident that the alternate motions of the piston depend on the opening and closing of the valves, alternately, in pairs. When the piston is at the top of the cylinder, the upper steam valve and the lower exhausting valve are to be opened, while the lower steam valve and the upper exhausting valve are to be closed. When the piston is at the bottom of the cylinder, this process is reversed.

642. Nature of the Crank.—It has been shown that the alternate motions of the piston-rod, determined by the *double-acting cylinder*, are communicated to the working end of the beam, to the curved motion of which they are adjusted by the contrivance of the *parallel motion*. The next object was to convert the *rectilinear* motion, thus produced, into a *rotatory* motion.

So long as the force of steam was employed for the mere purpose of raising water, no such motion was wanted; but, when its application was required for the purpose of turning the wheels of mills, of giving effect to the machinery of cotton manufactures and printing-presses, of propelling steam-vessels and other locomotive engines, it became necessary to impart a new direction to its operation. To obtain this object, the crank was introduced.

FIG. 164.



Crank.

643. The simplest idea of a crank is that of the *handle to a wheel;* its action is familiarly illustrated in the process of drawing water from a well; the bent handle attached to the wheel is first pushed out, then pulled in the opposite direction, and thus a continued rotatory motion is produced upon an axle. The application of this principle to the steam-engine, and the variations of pressure on the crank of a steam-engine, may be conveniently illustrated by curves.

644. This will be readily perceived by *Fig.* 164, which represents the lower portion of the connecting-rod, which works at its upper extremity on a pivot connected with the working extremity of the beam.

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642. What is the crank, and how does it act? 644. What are the dead points in the motion of the crank?

The lower extremity of the rod is connected by a movable joint at I, with the lever I K. The center or axis to which the rotatory motion is to be communicated, is indicated by the letter K. Hence, it would appear that, as the connecting-rod moves upward and downward, it would carry the lever, I K, round the center K, so as to occupy successively the positions denoted in the figure by the dotted shadows of the lever; and, thus, a continued rotatory motion would be communicated to the axis.

645. *Irregular Action of the Crank.*—On considering more closely the action of the crank, it will be found to be by no means continuous in its motion. There are *two positions* which the crank assumes in its circuit, in which the moving power has positively no effect whatever, in communicating a rotatory motion to it.

646. I. *When the piston is at the bottom of the cylinder*, the crank will be in the position denoted in the preceding figure; the joint, I, will be in a perpendicular line between the upper end of the connecting-rod and the center, K. It is obvious that, as the piston ascends in the cylinder, the connecting-rod will tend to push the joint, I, not to the right nor to the left of the dotted circle, but *directly downward* upon the axis, K.

647. II. *When the piston is at the top of the cylinder*, the crank will have performed half a revolution, and the joint, I, will be in a perpendicular line below the center, K. As the piston descends, the connecting-rod will tend to pull the joint I, not to the right nor to the left of the dotted circle, but *directly upward* upon the axis, K. It is evident that, if in either of these positions, the action of the crank were for a moment to cease, it would be out of the power of the piston to put it again into motion.

648. NATURE OF A FLY-WHEEL.—In impelling machinery by force, it is frequently necessary that *the force should be regulated.* This necessity may arise from several causes. There may be a want of uniformity in the *first moving power*, as in the single-acting engine of James Watt, in which the *descent* of the piston is effected by the pressure of steam, while its *ascent* is effected by a totally different means, viz.: by the pressure of the atmosphere. Or, there may be a want of uniformity in the *resistance* which the force has to overcome, as in the *crank* described in the preceding paragraph.

To regulate these inconveniences and equalize the motion, a large heavy wheel, called a *fly-wheel*, is connected with the ma-

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644. Explain this by Fig. 161 **648.** How does the fly-wheel continue the motion of the crank?

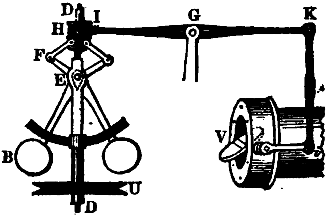
chinery, so as to receive its motion from the impelling power, to keep up the motion by its own inertia, and distribute it *equally* in all parts of its revolution. If the moving power slackens, the fly-wheel impells the machine forward; if the power tends to impel the machine too fast, the fly-wheel slackens it. The object of the fly-wheel, therefore, is to absorb, as it were, the surplus force at one part of the action of the machine, and to give it out when the action of the machine is deficient; by Leslie, it was well compared to a "reservoir which collects the intermittent currents, and sends forth a regular stream."

Uses of the Fly-Wheel.—The objects of the fly-wheel in the steam-engine, as here described, are obviously two-fold: first, to extricate the machine from the mechanical difficulties which occur at the *two stationary positions* of the crank; and, secondly, to equalize the effects of the varying leverage by which the first mover acts on the crank. But, besides the irregularity in the action of the crank, there are other causes which, in the absence of a fly-wheel, would disturb the uniform velocity of the engine: there are *variations of resistance*, and of *power*.

649. When the *resistance is increased*, or the moving power diminished, the momentum accumulated in the fly-wheel continues the motion with little diminution of its own velocity. It is not, however, pretended that the equalization of force produced by the fly wheel, is perfect; but, it is sufficient for ordinary purposes; and, its efficiency will be proportioned to the mass of matter in the circumference of the wheel, and to the square of the wheel's velocity. The next step in the progress of improvement was to regulate the velocity of the fly-wheel.

650. THE GOVERNOR.—Of all the contrivances for regulating the motion of machinery, this is said to be the most effectual. It will be readily understood by the following description of *Fig.* 165. It consists of two heavy iron balls, B, attached to the extremities of the two rods, B E. These rods play on a joint at E, passing through a mortice in the vertical stem D D. At F, these pieces are united, by joints, to the two short rods, F H, which, at their

FIG. 165.



The Governor.

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649. Does the fly-wheel completely equalize the motion of machinery? 650. What is the governor? How does the governor operate to equalize the motion of machinery?

upper ends, are again connected by joints at H, to a ring which slides upon the vertical stem, D D. Now it will be apparent that when these balls are thrown outward, the lower links connected at F, will be made to diverge in consequence of which the upper links will be drawn down the ring with which they are connected, at H. With this ring, at I, is connected a lever, having its axis at G, and, to the other extremity of which, at K, is fastened a vertical piece, which is connected by a joint to the valve V. To the lower part of the vertical spindle, D, is attached a grooved wheel, W, around which a strap passes, which is connected with the axis of the fly-wheel.

Now, when it so happens that the quantity of steam is too great, the motion of the fly-wheel will give a proportionate velocity to the spindle D D, by means of the strap around W, and by which, the balls, by their centrifugal force, will be widely separated; in consequence of which, the ring H will be drawn down. This will elevate the arm of the lever K, and by which the end, I, of the short lever, connected with the valve V, in the steam pipe, will be raised, and thus the valve turned so as to diminish the quantity of steam admitted to the piston. When the motion of the engine is slow, a contrary effect will be produced, and the valve turned so that more steam will be admitted to the engine.

651. *Connected View of the Double-acting Engine.*—We are now in a condition to understand the relation which the several parts of the engine, already separately described, bear to each other. In its general construction it resembles the single-acting engine of Watt, not described in the present work, but it differs from it in several important features. Among these, are its capability of performing twice the amount of work in the same time, from the simultaneous action of the pressure, and of the condensation of steam, at *each ascent and descent* of the piston; its near approximation to uniformity of power; its economy of heat, and consequently of fuel, by the diminution of cooling surface; and its reduced bulk. In the following engraving, taken from the valuable work of Tredgold, a section of this engine is illustrated; a few additional remarks to those which have already been made on its separate details, will serve to explain its general operation.

652. At the right is seen (*Fig.* 166) the great horizontal *steam tube*, S, which admits steam into the cylinder through the

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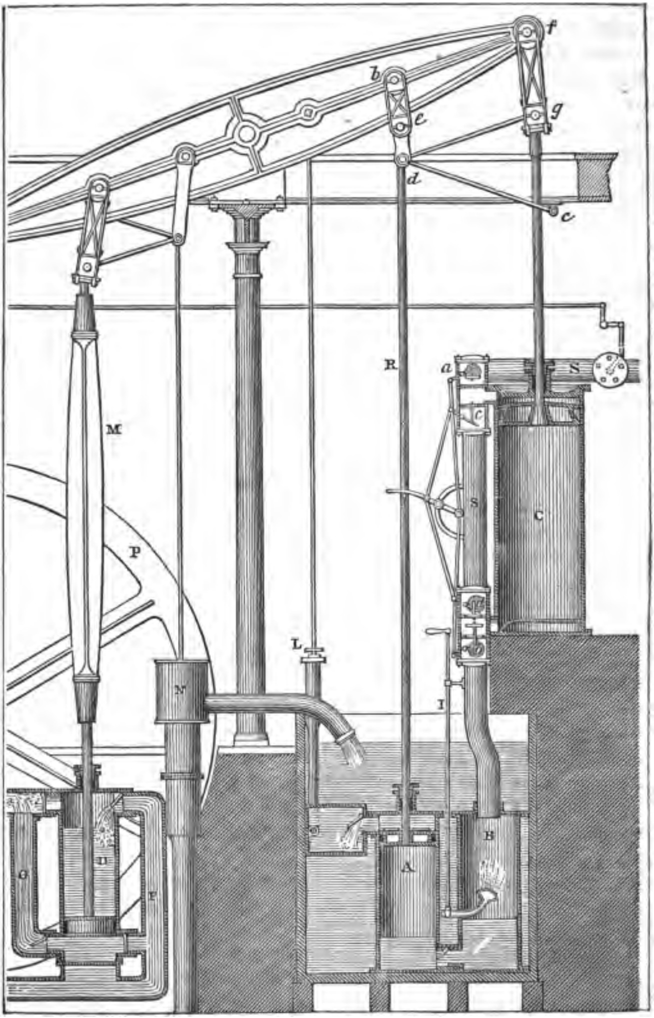
652. In Fig. 166, where is the steam-pipe?

FIG. 166.



Modern Steam-Engine.

throttle valve, which appears near S in the form of a disc. The boiler is omitted in the plate, but, its connection with the tube, and the means by which it is supplied with warm water, may be inferred from descriptions already given.

653. The *double-acting cylinder*, C, its two steam boxes and four valves, and the apparatus for working the valves, are the next objects which claim attention. These are explained by *Figs.* 162 and 163. The piston is at the top of the cylinder. The upper steam valve, *a*, is, therefore, represented as open for the admission of steam, the upper exhausting valve, *c*, as closed; the condition of the two lower valves is reversed. The operation of opening and closing these four valves is effected by a series of levers, terminating in one handle or *spanner*, which is worked by two pegs attached to the pump-rod, R.

Before the piston arrives at the bottom of the cylinder, the upper peg strikes the handle of the levers downward, and, in a moment, reverses the condition of the four valves. The steam from above the piston then rushes down through the perpendicular tube S, issues at the lower steam valve *d*, which will now be open, and forces up the piston; but, before the piston arrives at the top of the cylinder, the lower peg strikes the handle of the levers upward, the condition of the valves is again reversed, the steam below the cylinder rushes through the lower exhausting valve *b*, into the condenser B, and the *stroke* of the engine is repeated.

654. In the *condenser*, B, the steam meets with a *continual* jet of cold water. In the double-acting engine, condensation goes on equally during the descent and ascent of the piston, and the condensing jet is, therefore, incessantly at play. Engines with a condenser are called low-pressure engines. The variations which occur in the velocity of the piston, and the consequent variations in the quantity of steam discharged into the condenser, require corresponding variations in the quantity of condensing water; its amount is, therefore, regulated by the injection cock, which is worked by a lever and handle, I. The water produced by condensation of the steam is removed by the *air-pump*, A, and carried into the warm cistern, from which a portion of it is drawn by the pump, L, and conveyed to the boiler. The cistern containing the condenser, the air-pump, and the injection cock, is supplied with water by the pump, N, on the left side of the beam.

On the extreme left is the *fly-wheel*, a part of which is seen

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653. Which is the cylinder? 654. Which is the condenser?

at P, and to the axle of which is fixed the *crank*, the being moved by the connecting-rod attached to the end of the working-beam. To the fly-wheel is also attached the *governor;* but, these parts having already been explained, and, being unnecessary to the understanding of the whole, are omitted in the drawing.

On the right extremity of the beam is seen the apparatus which produces the *parallel motion.* The moving parallelogram is represented at *f*, *b*, *d*, *g;* the rod *d c* is the *radius rod:* it terminates the arc of the circle, through which the point *d* travels. At *e* is seen the extremity of the pump-rod, R, which is worked by the same machinery as that of the parallel motion.

655. Returning to the left side of the beam, we find the *pumping apparatus.* D represents the barrel of the pump, and M is the pump-rod, which is connected with the beam by mechanism similar to that of the parallel motion, already described. When the piston of the pump descends, the water is forced upward, through the pipe G, and conveyed, by appropriate channels, to a distance and height proportional to the power of the engine. The barrel of the pump is filled, through the pipe F, by means of machinery adapted to this purpose below; and, when the piston of the pump ascends, the valve at the left of the barrel opens, and the water rushes through in the same direction as that from the pipe G. The supply for the descent of the piston will rush in at the bottom valve, from F, and be raised through the pipe G, as before. The valves with which the piston of the air-pump is furnished are termed *clacks.*

HIGH—PRESSURE ENGINE.

656. In the *high-pressure* engines, the piston is pressed up and down by the force of the steam alone, and without the assistance of a vacuum. The additional power of steam required for this purpose is very considerable, being equal to the entire pressure of the atmosphere on the surface of the piston. We have already had occasion to show that on a piston of 13 inches in diameter the pressure of the atmosphere amounts to nearly two tons.

657. Now, in the low-pressure engine, in which a vacuum is formed on one side of the piston, the force of steam required to

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655. Which is the air-pump? Explain the water-pump. **656.** What is the difference between the high and low-pressure engines? **657.** What constitutes a low-pressure engine?

move it is diminished by the amount of atmospheric pressure nearly equal to the size of the piston.

658. But, in the high-pressure engine, the piston works in both directions against the weight of the atmosphere; and, hence, requires an additional power of steam equal to the weight of the atmosphere on the piston.

559. These engines are, however, much more simple and cheap than the low-pressure, since the condenser, cold water pump, air-pump, and cold water cistern, are dispensed with; nothing more being necessary than the boiler, cylinder, piston, and valves. Hence, for railroads and all locomotive purposes, the high-pressure engines are and must be used.

Low-Pressure in England.—With respect to engines used on board of steamboats, the low-pressure are universally employed by the English, and it is well known that few accidents from the bursting of machinery have ever happened in that country. In most of their boats, two engines are used, each of which turns a crank, and thus the necessity of a fly-wheel is avoided.

In this country, high-pressure engines are in common use for boats, though they are not universally employed. In some, two engines are worked, and the fly-wheel dispensed with, as in England.

660. *Accidents.*—The great number of accidents which have happened in this country, whether on board of low or high-pressure boats, must be attributed, in a great measure, to the eagerness of our countrymen to be transported from place to place with the greatest possible speed, all thoughts of safety being absorbed in this passion. It is, however, true, from the very nature of the case, that there is far greater danger from the bursting of the machinery in the high than in the low-pressure engines, since, not only the cylinder, but the boiler and steam pipes must sustain a much higher pressure, in order to gain the same speed, other circumstances being equal.

HORSE–POWER.

661. When steam-engines were first introduced, they were employed to work pumps for draining the English coal mines, thus taking the place of horses, which, from the earliest times of using coal, had performed this service.

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658. How much more force of steam is required in high than in low-pressure engines? 659. What parts are dispensed with in high-pressure engines? 660. What is said of accidents from steam in our country? 661. Where did the steam-engine first take the place of horses?

662. It being, therefore, already known how many horses were required to raise a certain amount of coal from a given depth, the powers of these engines were very naturally compared to those of horses; and, thus, an engine which would perform the work of ten horses was called an engine of *ten horse-power*. To this day, the same term is used, with the same meaning, though very few appear to know either the origin of the term, or the amount of power it implies.

Several engineers, after the term was thus used, made experiments, for the purpose of ascertaining the average strength of horses, with a view of fixing a standard of mechanical force, which should be indicated by the term *horse-power*.

This was done by means which it is not necessary here to describe.

663. Smeaton, a celebrated mechanical philosopher, estimated that the average power of the horse, working eight hours a day, was equal to the raising of 23,000 pounds at the rate of one foot per minute.

664. Messrs. Bolton and Watt caused experiments to be made with the horses used in the breweries of London, said to be the strongest in the world, and, from the result, they estimated that 33,000 pounds, raised at the rate of one foot per minute, was the value of a horse's power, and this is the estimate now generally adopted. When, therefore, an engine is said to be so many horses' power, it is meant that it is capable of overcoming a resistance equal to so many times 33,000 pounds, raised at the rate of one foot per minute. Thus, an engine of ten horse-power is one capable of raising a load of 330,000 pounds one foot per minute, and so at this rate, whether the power be more or less.

665. Power of Steam.—Experiment has proved that an ounce of water converted into steam will raise a weight of 2,160 pounds one foot.

666. A cubic foot of water contains 1,728 cubic inches, and the power, therefore, of a cubic foot of water, when converted into steam, will be equal to 2,160 multiplied by 1,728, equal to 3,732,480 pounds. This, then, expresses the number of pounds weight which a cubic foot of water would raise one foot when converted into steam, supposing that its entire mechanical force

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662. What is the origin of the term horse-power? 663. What was Smeaton's estimate of a horse's power? 664. What was Watt and Bolton's estimate of a horse's power? What is meant by a horse's power at the present time? How many horses would raise 33,000 pounds one foot per minute? 665. What is the power of a square inch of water converted into steam? 666. What is the power of a cubic foot of water converted into steam? How much power is lost in acting upon the engine?

could be rendered available. But, in practice, it is estimated that the friction and weight of the machinery in action require about four-tenths of the whole force, while six-tenths only remain as an actual mechanical power.

667. *Quantity of Water required for each Horse-Power.*—One horse-power, as already explained, is equal to a force which will raise 33,000 pounds one foot high per minute. This being multiplied by 60 will show the force required to raise the same weight at the rate of one foot per hour, namely, 33,000+60= 1,980,000 pounds.

668. Now the quantity of water required for this effect, will be found by considering, as already shown that a cubic inch of water in the form of steam, is equal to a force raising 2,160 pounds a foot. If we divide 1,980,000, therefore, by 2,160, we shall have the number of cubic inches of water required to produce a one-horse power, namely, 9,160. But we have already shown that only 6 parts out of 10 of the force of steam can be calculated on as a moving power, 4 parts being expended on the action of the engine. To find, then, the amount of waste in 916 cubic inches of water, we must divide that number by 6, and multiply the result by 4, when we shall have 610 as the number of cubic inches of water wasted. The total quantity of water, therefore, which is turned into steam per hour, to produce a one-horse power, is equal to 610 added to 916, namely, 1,526 cubic inches. Hence we see the necessity of the immense capacities of the boilers of large steamboats.

669. *Amount of Mechanical Virtue in Coal*—For more than thirty years, the engineers of many of the English coal mines have published annual accounts of their experiments with the steam-engines under their care, for the purpose of ascertaining the exact amount of coal required to perform certain duties. The results of these experiments are among the most curious and instructive facts which the lights of science at the present day, have thrown upon the manufacturing arts. They were entirely unexpected to the owners of the mines, and equally so to men of science.

Report of Engineers.—In the report of the engineers thus employed, for 1835, it was announced that a steam-engine employed at a copper mine in Cornwall, had raised, as its average work, 95 millions of pounds a foot high, with a *single bushel* of bituminous coal.

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667. How many cubic inches of water is required to produce a one-horse power? 668. How do you find how many cubic inches of water there are in a one-horse power? 669. What amount of weight is it said a bushel of coal will raise by means of steam? What was the weight raised by the second trial?

This mechanical effect was so enormous and so unexpected, that the best judges of the subject considered it beyond the bounds of credulity; the proprietors, therefore, agreed that another trial should be made in the presence of competent witnesses; when, to the astonishment of all, the result exceeded the former report by 30 millions of pounds. In this experiment, for every bushel of coal consumed under the boiler, the engine raised 125½ millions of pounds one foot high.

670. On this subject, Dr. Lardner, in his treatise on the steam-engine, has made the following calculations:—

A bushel of coal weighs 84 pounds, and can lift 56,027 tons a foot high, therefore, a pound of coal would raise 667 tons to the same height; and an ounce would raise 42 tons one foot high, or it would lift 18 pounds a mile high.

Since a force of 18 pounds is capable of drawing two tons upon a railway, it follows that an ounce of coal would draw 2 tons a mile, or 1 ton two miles. (In the common engines, however, the actual consumption of coal is equal to about 8 ounces per ton for every mile.)

The great Egyptian pyramid has a base of 700 feet each way, and is 500 feet high; its weight amounting to 12,760,000,000 pounds. To construct it, is said to have cost the labor of 100,000 men for 20 years. Yet according to the above calculations, its materials could have been raised from the ground to their present positions by the combustion of 479 tons of coal.

EXPLOSION OF STEAM-BOILERS.

671. In certain cases, where the explosion of steam-boilers have been peculiarly sudden, violent and unexpected, and no other cause could be reasonably assigned, it has been supposed that the generation and subsequent combustion of *hydrogen gas* in the over-heated iron vessel, has been in some way the cause of the explosion. On this subject a multiplied series of experiments, made by a Committee of the Franklin Institute, of Philadelphia, and at the suggestion and expense of the United States Treasury department, have shown, that the generation of hydrogen in steam-boilers, however high their heat may be, never takes place. Want of room forbids the insertion of the detail of these experiments, but it is sufficient to state here, that after many trials with the express design of forming hydrogen

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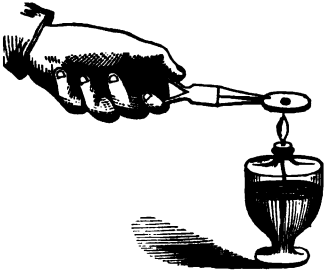
670. What weight will a pound of coal raise? How great a force may an ounce of coal be made to produce? What is the size and weight of the great pyramid of Egypt? What weight of coal would be required to raise its materials to their present elevation? 671. What is said of the generation of hydrogen in steam-boilers? Does hydrogen explode alone?

in a steam-boiler, if possible, they never produced a trace of this gas, from the decomposition of the water.

672. *Hydrogen not Explosive.*—Even, if the gas in question was always formed in over-heated boilers, no danger could accrue from its presence, since hydrogen never explodes without being mixed with oxygen or common air, neither of which ever exists in a steam-boiler when in use. Besides, were these two gases in the boiler ready for explosion, still no danger would exist, since they never take fire except from contact with flame, hence all danger from hydrogen in a steam-boiler exists only in imagination.

673. *Globular or Spheroidal state of Water.*—The spheroidal state of water in steam-boilers has lately attracted the attention of philosophers, as the source of explosions. This subject affords some highly curious and interesting experiments, all, however, founded on the fact, that water is not converted into steam when subjected to high degrees of heat. To those who have not examined the subject, this assertion, no doubt, seems preposterous and untrue. (*See Fig.* 167.)

FIG. 167



Spheroidal Water.

674. But let us observe the facts. 1st. Every blacksmith knows that a white-hot bar of iron plunged into water requires some time to cool before it yields the least sign of steam. Its glowing heat repels the water, and no steam rises until the metal becomes black. 2d. The spheroidal state of water is seen by the following experiment. Hold a little cup of platina or silver foil, or of bright copper, brass or iron, over an alcohol lamp, until the metal is red-hot, and then holding it still over the flame, with a slip of paper throw a drop of water into the heated cup, taking care not to throw in too much. The water will instantly take the globular form, and roll about like little balls of mercury, remaining for some time without any diminution by conversion into steam, though the cup is over the blazing alcohol, and red-hot. If now the cup be removed from

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672. What mixtures make hydrogen explode? How may this be set on fire? 673 What is said of the spheroidal state of water? 674. How may this state of water be exhibited?

the heat, and allowed to cool for a moment, the little spheroids will be converted into steam with a minute explosion, affording a very curious and interesting experiment, to all who witness it.

675. *Remarks.*—In connection with the spheroidal theory, we must connect the account we have given of the explosion of the steam-boiler at the Car-factory at Hartford. Now, whoever will make the experiments above detailed, and consider that the boiler with its flues, at least the three upper ones, each 15 inches in diameter, might have been to a considerable extent naked, and thus exposed to a red heat, will by no means think it improbable that the spheroidal state of the water, might have resulted in that awful accident.

It indeed seems highly improbable that the gradual accumulation of the pressure of steam could have produced the effects described, for in cases of such accumulation, experience has taught us that there will be a rent or giving way of some weak part of the boiler, and not such a wide and general destruction as would have been the product of the firing of a large quantity of gun-powder, as was the case in question. (*See p.* 201.)

LOCOMOTIVE.

676. This word, from the Latin, means "moving from place to place," and is applied to steam-engines used on railroads.

Our limits will only allow a short description of this wonder-working machine, which, during the last quarter of a century, has been the means, with respect to *locomotion*, of converting days into hours, and weeks into days.

The principal external parts of a locomotive are indicated by the letters on *Fig.* 168.

677. The *truck wheels*, A A, are of cast iron, about two and a half feet in diameter, all of them connected by an iron frame, in the center of which, the end of the boiler rests on a pivot, so as to allow a revolving motion, in order to accommodate the engine to short curves in the road.

678. The *boiler*, B, which makes the chief bulk of the locomotive, is of rolled iron, about 12 feet long, of great weight, and strength, to resist the pressure of the steam. It is put together by iron bolts, only an inch or two apart, so as to be perfectly steam-tight under the greatest force.

Above R, is the *fire-box*, with a door, not shown, for admission of the wood. The interior of the boiler is composed of

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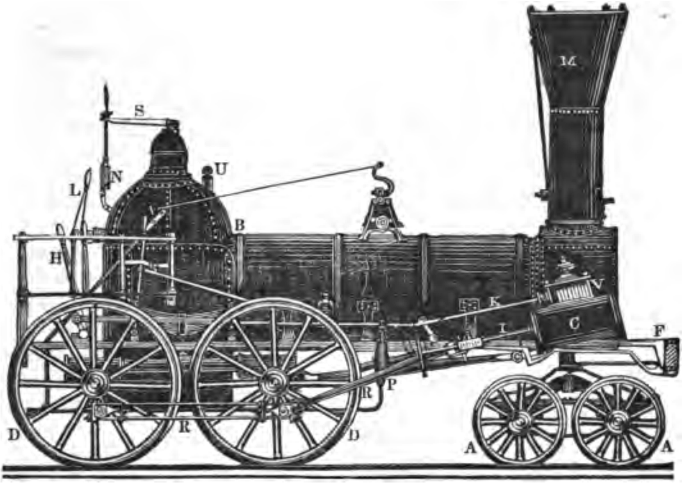
675. What reason have we for believing that the Car-factory explosion was caused by the spheroidal state of the water?

FIG. 168.



Locomotive Steam-Engine.

about 100 copper tubes, through which the smoke and heat pass to the chimney. These tubes are entirely surrounded by water, which the heat emitted by the tubes, as they pass through it, converts into steam.

679. The *pump*, P, supplies the boiler with water, which it takes from the tender, not shown, but which is connected with the locomotive, and on which the fuel is carried. In cold weather, the waste steam heats this water before it is admitted to the boiler.

680. The *steam-cylinder*, C, communicates with the boiler by a short pipe, for admission of the steam. In this cylinder works the piston, which gives motion to the engine.

The cylinder is externally of brass, kept polished in order to prevent the radiation of the heat. Its diameter is about 12 inches, and the movement of the piston 20 inches. This is furnished with valves, working in the same manner as those already described for the steam-engine.

The alternate, horizontal motion of the piston, is so connected with the driving-wheels, as to give them a rotatory motion, by which the engine is moved.

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680. Describe the steam-cylinder, and tell its use

681. This is done by means of the *connecting-rods* R, R which are jointed to the spokes of the drivers at one end, and to the piston-rod I, at the other, thus connecting the force of the steam with that part of the engine by which the whole is actuated.

The immense force which the steam exerts, is shown by the power required to draw 20 or 30 cars, loaded with hundreds of tons, at the rate of 20 or 30 miles an hour. And yet a single locomotive will draw such a load even up an inclined plane.

682. The *driving-wheels*, D D, by which the locomotive is moved, are of cast iron, with strong wrought iron tire, so as to withstand any shock which it is considered possible to happen, since on the strength of these the lives of hundreds of passengers may depend, as the fracture of one of them may cast the engine and entire train from the rails. In diameter they are from 5 to 6 feet.

683. These four wheels are connected together, not only by the *connecting-rods*, but also by a strong iron frame, and by the axle-trees which revolve with them, so that the greatest amount of adhesion to the rails is obtained. This is a most important point in the construction of the engine, since by this means all the wheels must act together, thus forming by their adhesion to the rails a single fulcrum, acting as a lever of the third kind, (319,) of which the spoke of the wheel is the lever, and the piston, through the connecting-rods, the power. If therefore, one of the wheels slips on the rail, they must all slip, it being this connection by which locomotives draw such enormous loads over inclined planes.

684. The *lever*, L, opens the *throttle-valve*, by which the steam is admitted to the cylinder from the boiler. When the engine is to be started, the engineer opens this communication; when the piston begins its alternate motion, the drivers their revolutions, and the engine and train their progress.

685. The *reversing-handle*, H, acts on machinery for that purpose, in such a manner as to reverse the motion of the driving-wheels, giving them a backward instead of a forward action in a moment. It is used whenever there is danger of a collision, or when it is desired to give the engine a reverse movement on any occasion.

The *spring-balance*, N, is connected with a graduated scale by which the pressure of the steam is indicated.

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681. What are the connecting-rods? 682. What are the wheels which give motion to the locomotive? Why are the driving-wheels made of great strength? 683. Why are these four wheels connected? On what principle do these wheels act? 684. Describe the manner of starting the engine. 685. What is the use of the reversing handle?

686. The *safety-valve lever*, S, is connected with a valve, so constructed as to open when the pressure is above a certain amount, and thus allow the steam to escape. When properly adjusted, this may be the means of saving the engine from one of the most fearful of accidents, that of bursting the boiler.

687. The *smoke-pipe*, M, is connected with the fire-box, by means of the copper tubes running through the boiler, already mentioned. Various contrivances have been invented to arrest the sparks which are emitted with the smoke, and which have often set fire to bridges and other buildings. For this purpose a wire gauze placed across the mouth of the pipe, has been the most efficient.

The *engine-frame*, F, is made of wrought iron, strongly connected by rivets, and to which all parts of the locomotive are attached, and by which they are combined into a single instrument, to be moved forward as a great power, by means of which hundreds of tons are to follow.

The *valve-box*, V, contains the valves of the cylinder, which have already been described while treating of the *steam-engine.*

The *steam-whistle*, U, is composed of a cylinder, with peculiar internal arrangements, on which the steam from the boiler being admitted, by a valve, makes a well-known sound, heard at the distance of many miles. By its report, the degrees of pressure of the steam are indicated.

The *slide-valve rod*, K, works the valve by which the steam is admitted from the boiler to the cylinder, and by which the piston is moved.

688. *Springs of the Boiler.*—The boiler rests on steel springs, composed of many flat pieces of different lengths, laid one on the other, forming a pyramidal pile six or eight inches high, and of sufficient strength to bear many tons. By the slight motion of these springs, the concussion between the engine and the rails is prevented, and without which neither would preserve its integrity for an hour, under the tremendous shocks the weight and motion of the engine sometimes give.

ADHESION TO THE RAILS.

689. We have already noticed the necessity of so combining the action of the driving-wheels, as to make them form an individual fulcrum, by their adhesion to the rails.

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686. How does the safety-valve act, and for what purpose? 687. What are the means of arresting sparks from the smoke-pipe? 688. What is said of the springs on which the boiler rests? 689. Why are the driving-wheels so connected as to form an individual fulcrum? What is the weight of some engines?

On this the motion of the engine, and consequently of the whole train depends, and hence the necessity of the enormous weight of the locomotive. On roads, through hilly sections of the country, the weight of the engine is made to correspond to the inclination of the grade. Were this not the case, as the adhesion depends on the weight, the wheels would revolve without advancing, and thus the whole train would remain motionless, because the weight, with the inclination, required a greater force than the power of the engine. On such roads where heavy freight trains are to be drawn, the weight of the engine sometimes amounts to 40 or 50,000 pounds.

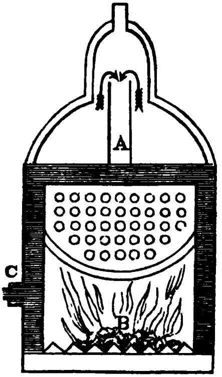
690. In all cases, the invariable condition must be, that the force be greater than the resistance, otherwise no progress will be effected; and as we have already seen, the force depends on the adhesion, and this on the weight, so it is obvious that a ponderous engine only, will draw a heavy train over a rapid inclination. It is estimated that the force of adhesion amounts to one-sixth of the weight of the drivers on the rails.

691. *Section of the Boiler.*—It has been noticed above, that locomotive boilers are furnished with copper tubes, passing from the fire-box to the chimney. The ordinary number of these tubes is 120, and their diameters about two inches. If larger than this they are liable to collapse by the pressure of the steam, and if smaller, they soon become clogged by the soot.

The end of such a boiler is represented by *Fig.* 169. The fire-box with the grate for fuel, is seen at B, above which are the ends of the tubes. In *Fig.* 168, these parts are above R A shows the dome, above the fire-box, and which forms a part of the boiler, being open and containing the steam as it is formed.

692. The steam is conveyed to the cylinders from the large pipe, seen at the upper part of the dome, the two arrows showing that it is admitted from all directions. The mouth of

FIG. 169.



Fire-Box and Boiler.

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690. What is said of the proportion between the weight of the engine and the grade of the road? What must be the condition with respect to the weight and force? What is the estimate between the force of adhesion and the weight of the drivers? **671.** Show by Fig. 169, the situations of the fire-box, steam-pipe, tubes, and grate. **692.** Why is the mouth of the steam-pipe so high in the dome?

this pipe is thus elevated, in order to avoid the admission of the water when in the state of the greatest ebullition.

The fire-box is made of thick, rolled iron, with double walls, about three inches apart, the space between them being filled with water, so that the fire is surrounded with water, except at the door, where the fuel is admitted.

693. The water is pumped into the side of the fire-box at C, which opens into the boiler.

The boiler is only about half filled with water, the upper part being devoted to steam.

The boiler is made of thick, rolled iron, strongly riveted together, and in the form of a cylinder, being that which best resists the pressure of the steam.

In order to confine the heat, or prevent radiation, boilers are covered with wood, in the form of narrow strips of board, over which there is a covering of sheet-iron.

694. Locomotive engines are always on the high-pressure principle, because such engines are more simple in structure than those of low-pressure, the former not requiring the condensing apparatus which is indispensable in the latter.

EXPLOSION OF A STEAM-BOILER AT HARTFORD.

695. One of the most extraordinary steam explosions on record, in respect to some of its features, and its consequences, took place at the Grove Car-factory in Hartford, Conn., on March 2d, 1854.

The number of persons killed by this explosion was 19; and the number wounded in various degrees, some of which died of their wounds, was 23. These were all men at work in different parts of the factory, but most of them in the blacksmith's shop, which was situated near the boiler.

For the benefit of the student, we here give figures showing the form and mechanism of the boiler; the place of the fire and chimney, and other particulars, which will be learned on inspection.

A longitudinal section of the boiler is represented by *Fig.* 170, the arrows showing the direction of the smoke and heat, and by which it will be observed that the fire was made under the outside of the shell of the boiler, the heat passing to its further extremity, and then returning by the flues, surrounded with the water, to the chimney, which was situated at the end containing the fire-place. The heat was therefore communica-

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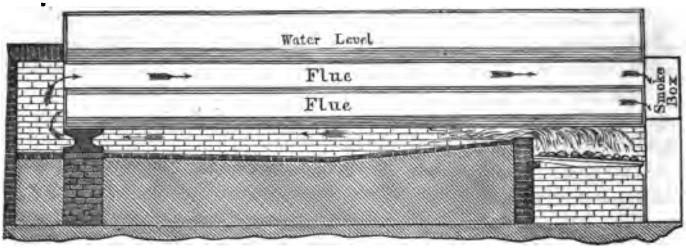
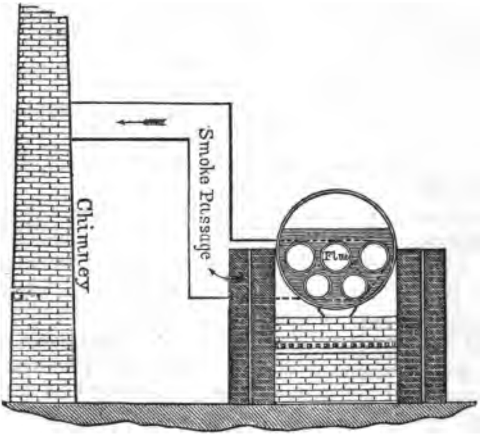
693. Where is the water admitted to the boiler? 694. Why are locomotives on the high-pressure principle?

FIG. 170.



ted to the water, not only on the outside of the boiler, but also by means of the flues through the middle, this being the common method of heating boilers of this kind.

FIG. 171.



A cross section of the boiler is shown by *Fig.* 171, where the ends of the five flues, with the smoke-pipe, leading from the boiler to the chimney, are represented. This chimney of brick, is 125 feet high. The upper three flues are each 15 inches in diameter, and the two lower ones 12 inches.

Description of the Buildings.—The main building of this eat factory was 200 feet long and 60 wide, to which had been added another building 55 feet long, and 24 wide, making this range equal to 255 by 84 feet; the whole of brick, and three stories high. This stood north, extending north-east and north-west of the boiler. The whole of this building was more or less damaged, and the part nearest the boiler, say within 15 or 20 feet, was thrown down, and entirely demolished.

Running south of this, and opposite the boiler, being separated from it by a brick wall 18 inches thick, was the blacksmith's shop, 30 by 40 feet, and two stories high; and still south of this, was the paint shop, 100 feet long and 60 feet wide.

In addition to these was the carriage-house for storing and finishing the cars, but this sustained, when compared to the others, but little injury.

Destruction.—All the buildings described were more or less injured, but the main building nearest the boiler, the smiths' shop, and the paint shop, chiefly suffered. The force of the explosion was such as entirely to demolish the smiths' shop, first reducing almost to atoms the 18 inch wall standing between it, and the boiler. In this direction, but about 60 feet from the boiler, the end wall of the paint shop, beyond the smiths' shop was demolished. These were south of the explosion.

At the north and east end the destruction was little less than at the south, a part of the walls of the three story main building being blown into fragments, and with the others, reduced to heaps of rubbish. Such indeed were the effects of this terrible explosion, that the most solid brick walls within 40 or 50 feet of the boiler did not for an instant resist its force, but were broken as though an earthquake had done its work in the midst of the building.

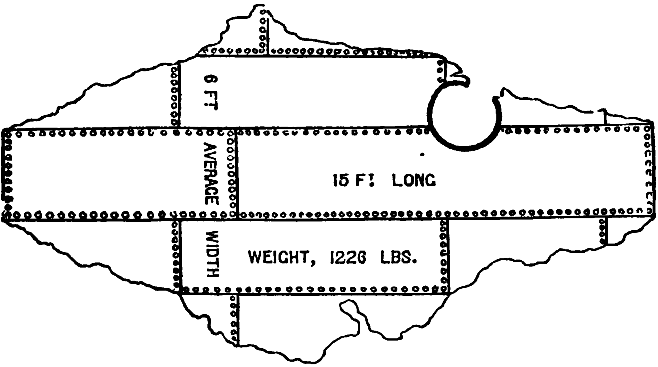
From the above description, it will be seen that a large portion of one of the most extensive and costly manufacturing establishments of the kind in the country, was blown into fragments by the explosion of a boiler only 24 feet long, and 5 feet in diameter.

No description can convey to the reader any adequate conception of the horrors of that scene. Almost entire buildings of brick, from two to three stories high, with the engines and tools of the various mechanical arts, and half finished work, lay piled in promiscuous ruin. But of this destruction of property, no notice was taken, for under and about these ruins lay the dead, dying, or wounded bodies of more than forty men, who a second before the explosion had been in full health and in the exercise of all their muscular powers. But of these scenes we will attempt no further description.

Number of men.—The number of workmen employed in the various parts of these buildings was about 270, at the moment of the disaster. But the chief loss of life happened in the smiths' shop, nearly all who were there, being either killed instantly, or severely wounded.

Fragment of the Boiler.—Although the above account shows the power of steam in a manner hardly to be conceived, yet there was no single circumstance which displayed its effects so distinctly and awfully as the fragment of the boiler, an outline of which is shown by *Fig.* 172. This was thrown through the roof of the smiths' shop, and then lodged on the roof of the paint shop, at the distance of about 200 feet from its starting point.

FIG. 172.



Its length was 15 feet, and its weight 1,220 pounds. The smooth, round aperture was the place of admission into the boiler, having had a plate of iron opening on the inside as a door.

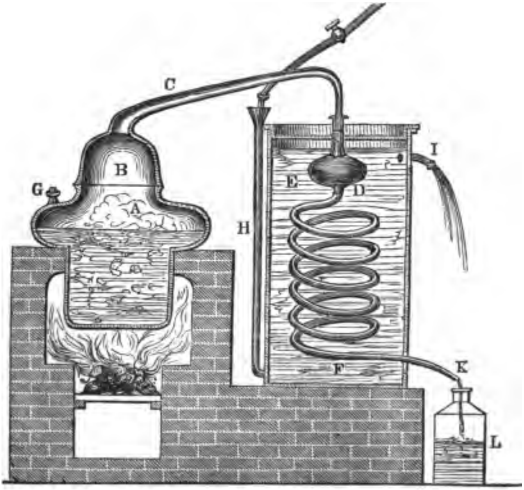
Force of the Steam.—Perhaps there is no instance on record where the power of steam from a boiler of the same dimensions, has been equal to that here described; and it is difficult for any one, even after reviewing the consequences as we did, to conceive how it could have been possible that the quantity of steam contained in that boiler could have produced such tremendous effects. Indeed, had the whole space been filled with gun-powder, and this exploded in an anstant, it is not probable that the consequences, with respect to mechanical force, would have been so terrible as those here exhibited.

Remarks.—Having thus shown the student how stationary steam-boilers are constructed, together with sufficient proofs of the tremendous power of confined steam, we find that the space allotted to this subject has already been occupied, and we can only add, that after a careful examination of the remains of the boiler, our theory of the cause of the explosion is the spheroidal state of the water, induced by over-heating of the boiler, and its being suddenly cooled by the admission of a large quantity of water. A statement of this theory is contained under "*Globular or Spheroidal state of Water.*" (673.)

DISTILLATION.

696. This process is employed for the separation of a volatile substance, from another less volatile, by means of heat. Thus all kinds of spiritous liquors are procured by distillation.

FIG. 173.



Distillation.

The spirit itself being the product of fermentation, remains with the fermented compound, until separated by heat. Thus brandy is procured from wine, and whiskey from fermented rye, by this process.

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696. Explain by Fig. 173, the process of distillation.

697. The apparatus for this purpose is represented by *Fig.* 173. It consists of a copper still, A, placed over a furnace, and surmounted with the dome-shaped head, B. The head terminates in the bent tube. C, which is continued in the coiled tube, D, both made of lead or tin. The coiled tube is called the *worm*, and descends through the cistern E F, opening at K, into the vessel, L. The tube H, with the funnel at the top, opens into the cistern near the bottom. The tubulure G, opens to receive the fermented liquor, and then is stopped. As the water is heated by the passage of the distilled spirit through the worm it rises up, and is discharged at the tube, I. As it is necessary for the condensation of the spirit, that the worm should be kept cold, a stream of water is directed into the cistern by the tube opening into H.

698. *Process.*—The fermented liquor being introduced into the still, A, and fire kindled under it, the spirit rises by means of the heat, and being condensed in the worm, is discharged into the vessel, L, either by drops, or in a small stream.

CHAPTER X.

ACOUSTICS.

699. *Acoustics is that branch of natural philosphy which treats of the origin, propagation, and effects of sound.*

700. *Vibration of Solids.*—When a sonorous, or sounding body is struck, it is thrown into a tremulous or vibrating motion. This motion is communicated to the air which surrounds us, and by the air is conveyed to our ear drums, which also undergo a vibratory motion, and this last motion throwing the auditory nerves into action, we thereby gain the sensation of sound.

If any sounding body of considerable size is suspended in the air and struck, this tremulous motion is distinctly visible to the eye, and while the eye perceives its motion, the ear perceives the sound.

701. *Proof by the Air-Pump.*—That sound is conveyed to the ear by the motion which the sounding body communicates to

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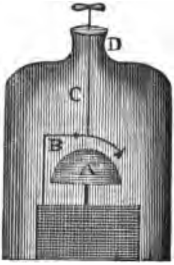
699. What is acoustics? 700. When a sonorous body is struck within hearing, in what manner do we gain from it the sensation of sound? 701 How is it proved that sound is conveyed to the ear by the medium of the air?

the air, is proved by an interesting experiment with the air-pump.

702. This is done by a little piece of mechanism shown by *Fig.* 174. It consists of a block of lead weighing a pound or two, into which is inserted the standard of the bell, A. A piece of wire, also fixed to the lead, is bent over the bell at B, to which is jointed the handle of a small hammer. At half an inch from the joint, the handle passes through the end of the sliding-rod, C, which passes air-tight through the stuffed collar of the glass receiver, D.

FIG. 174.



About Sound.

Now, it is obvious, by the figure, that on working the sliding-rod by its handle, the hammer will strike the bell, the sound of which may be heard to a considerable distance. But, if the receiver be set on the plate of an air-pump, and the air exhausted, its sound will become less and less audible, until a vacuum is formed, when, although the hammer is made to strike the bell, no sound will be heard. The lead should be placed on a piece of cotton batting, so as not to transmit the sound through the solid on which it stands.

DIVING-BELL.

703. On the contrary, when the air is more dense than ordinary, or when a greater quantity is contained in a vessel than in the same space in the open air, the effect of sound on the ear is increased. This is illustrated by the use of the *diving-bell.*

The diving-bell is a large vessel, open at the bottom, under which men descend to the beds of rivers, for the purpose of obtaining articles from the wrecks of vessels. When this machine is sunk to any considerable depth, the water above, by its pressure, condenses the air under it with great force. In this situation, a whisper is as loud as a common voice in the open air, and an ordinary voice becomes painful to the ear.

704. *Effects in High Places.*—Again, on the tops of high mountains, where the pressure or density of the air is much less than on the surface of the earth, the report of a pistol is heard only a few rods, and the human voice is so weak as to be inaudible at ordinary distances.

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702. Describe the mechanism, Fig. 174, by which this is proved. 703. When the air is more dense than ordinary, how does it affect sound? 704. What is said of the effects of sound on the tops of high mountains?

Thus, the atmosphere which surrounds us is the medium by which sounds are conveyed to our ears, and, to its vibrations we are indebted for the sense of hearing, as well as for all we enjoy from the charms of music.

705. *Solids conduct Sound.*—The atmosphere, though the most common, is not, however, the only or the best conductor of sound. Solid bodies conduct sound better than elastic fluids. Hence, if a person lay his ear on a long stick of timber, the scratch of a pin may be heard from the other end, which could not be perceived through the air.

706. *The Earth conducts Sound.*—The earth conducts loud rumbling sounds made below its surface to great distances. Thus, it is said, that, in countries where volcanoes exist, the rumbling noise which generally precedes an eruption is heard first by the beasts of the field, because their ears are commonly near the ground, and that, by their agitation and alarm, they give warning of its approach to the inhabitants.

707. The Indians of our country, by laying their ears on the ground, will discover the approach of horses or men when they are at such distances as not to be heard in any other manner.

708. *Velocity of Sound.*—Sound is propagated through the air at the rate of 1,142 feet in a second of time. When compared with the velocity of light, it, therefore, moves but slowly. Any one may be convinced of this by watching the discharge of cannon at a distance. The flash is seen apparently at the instant the gunner touches fire to the powder; the whizzing of the ball, if the ear is in its direction, is next heard, and, lastly, the report.

709. *Biot's Experiment.*—Solid substances convey sounds with greater velocity than air, as is proved by the following experiment, made at Paris, by M. Biot:—

At the extremity of a cylindrical tube, upward of 3,000 feet long, a ring of metal was placed, of the same diameter as the aperture of the tube; and, in the center of this ring, in the mouth of the tube, was suspended a clock-bell and hammer. The hammer was made to strike the ring and the bell at the same instant, so that the sound of the ring would be transmitted to the remote end of the tube, through the conducting power of the tube itself, while the sound of the bell would be transmitted through the medium of the air inclosed in the tube. The ear

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705. Which are the best conductors of sound, solid or elastic substances? 706. What is said of the earth as a conductor of sounds? 707. How is it said that the Indians discover the approach of horses? 708. How fast does sound pass through the air? What is said of the firing of cannon with respect to sound? 709. Which convey sounds with the greatest velocity, solid substances or air?

being then placed at the remote end of the tube, the sound of the ring, transmitted by the metal of the tube, was first heard distinctly, and, after a short interval had elapsed, the sound of the bell, transmitted by the air in the tube, was heard. The result of several experiments was, that the metal conducted the sound at the rate of about 11,865 feet per second, which is about ten and a half times the velocity with which it is conducted by the air.

710. *Sound Reflected.*—Sound moves forward in straight lines, and, in this respect, follows the same laws as moving bodies and light. It also follows the same laws in being reflected, or thrown back, when it strikes a solid or reflecting surface.

711. ECHO.—If the surface be smooth, and of considerable dimensions, the sound will be reflected, and an echo will be heard; but, if the surface is very irregular, soft, or small, no such effect will be produced.

In order to hear the echo, the ear must be placed in a certain direction, in respect to the point where the sound is produced, and the reflecting surface.

If a sound be produced at A, *Fig.* 175, and strike the plane surface, B, it will be reflected back in the same line, and the echo will be heard at C or A. That is, the angle under which it approaches the reflecting surface, and that under which it leaves it, will be equal.

712. Whether the sound strikes the reflecting surface at right angles, or obliquely, the angle of approach and the angle of reflection will always be the same and equal.

This is illustrated by *Fig.* 176, where, suppose a pistol to be fired at A, while the reflecting surface is at C; then, the echo will be heard at B, the angles 2 and 1 being equal to each other.

713. *Reverberation of Sound.*—If a sound be emitted between two reflecting surfaces, parallel to each other, it will reverberate, or be answered backward and forward several times.

Thus, if the sound be made at A, *Fig.* 177, it will not only rebound back again to A, but will also be reflected from the points C and D; and, were such reflecting surfaces placed at every point around a circle from A, the sound would be thrown back from them all, at the same instant, and would meet again at the point A.

We shall see, under the article Optics, that light observes ex

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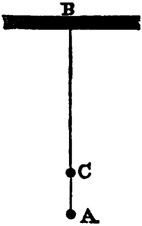
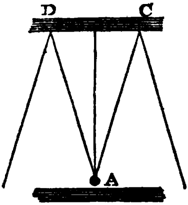
709. Describe the experiment proving that sound is conducted by a metal with greater velocity than by the air. 710. In what lines does sound move? 712. Explain Fig. 176, and show in what direction sound approaches and leaves a reflecting surface.

FIG. 175.



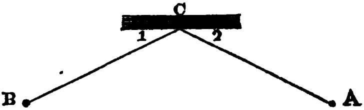
Echo.

FIG. 177.



Reverberation.

FIG. 176.



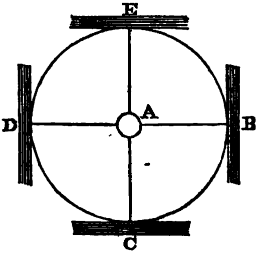
Reflection of Sound.

actly the same law in respect to its reflection from plane surfaces, and that the angle at which it strikes is called the *angle of incidence*, and that under which it leaves the reflecting surface is called the *angle of reflection.* The same terms are employed in respect to sound.

714. *Reflection in a Circle.*—In a circle, sound is reflected from every plane surface placed around it; and, hence, if the sound is emitted from the center of a circle, this center will be the point at which the echo will be most distinct.

Suppose the ear to be placed at the point A, *Fig.* 178, in the center of a circle; and, let a sound be produced at the same point, then it will move along the line A E, and be reflected from the plane surface, back on the same line, to A; and, this will take place from all the plane surfaces placed around the circumference of a circle; and, as all these surfaces are at the same distance from the center, so the reflected sound will arrive at the point A, at

FIG. 178.



Reflection in a Circle.

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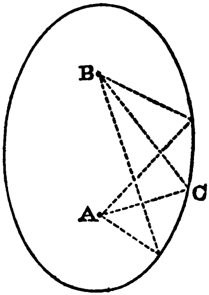
713. What is the angle under which sound strikes a reflecting surface called? What is the angle under which it leaves a reflecting surface called? Is there any difference in the quantity of these two angles? 714. Suppose a pistol to be fired in the center of a circular room, where would be the echo?

the same instant; and the echo will be loud in proportion to the number and perfection of these reflecting surfaces.

715. WHISPERING GALLERY.—It is apparent that the auditor, in this case, must be placed in the center, from which the sound proceeds, to receive the greatest effect. But, if the shape of the room be oval or elliptical, the sound may be made in one part, and the echo will be heard in another part, because the ellipse has two points, called foci, at one of which, the sound being produced, it will be concentrated in the other.

FIG. 179.



Whispering Gallery.

Suppose a sound to be produced at A, *Fig.* 179, it will be reflected from the sides of the room, the angles of incidence being equal to those of reflection, and will be concentrated at B. Hence, a hearer, standing at B, will be affected by the united rays of sound from different parts of the room, so that a whisper at A will become audible at B, when it would not be heard in any other part of the room. Were the sides of the room lined with a polished metal, the rays of light or heat would be concentrated in the same manner.

The reason of this will be understood when we consider that an ear, placed at C, will receive only one ray of the sound proceeding from A, while, if placed at B, it will receive the rays from all parts of the room. Such a room, whether constructed by design or accident, would be a *whispering gallery.*

716. *Successive Reflections of Sound.*—Several reflecting surfaces may be so situated in respect to distance and direction, that a sound, proceeding from a certain point, will be reflected, first from one surface, and then from another, at a little distance, afterward from a third, and so on; or, it may be reflected from the first surface to the second, and from the second to the third, and from this to a fourth, and so on, even, it is said, to the number of eight or ten.

717. According to the distance at which the speaker stands, a reflecting surface will return the echo of several, or of fewer syllables; for, in order to avoid confusion, all the syllables must be uttered before the echo of the first syllable reaches the ear.

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715. Explain Fig. 179, and give the reason. Suppose a sound to be produced in one of the foci of an elipse, where then might it be most distinctly heard? 716. What number of echoes are said to happen from one sound? 717. How many syllables are pronounced in a second?

In a moderate way of speaking, about 3½ syllables are pronounced in one second, or seven syllables in two seconds. Therefore, when an echo repeats seven syllables, the reflecting surface is 1,142 feet distant; for, sound travels at the rate of 1,142 feet per second, and the distance from the speaker to the reflecting object, and again from the latter to the former, is twice 1,142 feet. When the echo returns 14 syllables, the reflecting object must be 2,284 feet distant, and so on.

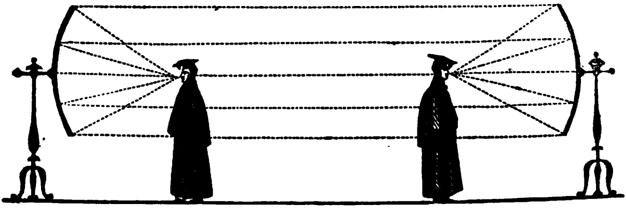
718. It is stated that a famous echo in Woodstock, (England,) repeats seventeen syllables in the day, and twenty in the night; and, on the north side of Shepley church, in Sussex, it is said that an echo repeats distinctly, under favorable circumstances, twenty-one syllables.

719. *Effects of Surface.*—On a smooth surface, the rays, or pulses of sound, will pass with less impediment than on a rough one. For this reason, persons can talk to each other on the opposite sides of a river, when they could not be understood at the same distance over the land. The report of a cannon at sea, when the water is smooth, may be heard at a great distance; but, if the sea is rough, even without wind, the sound will be broken, and will reach only half as far.

REFLECTION BY MIRRORS.

In some traveling exhibitions, the principle in question has been made a matter of curious and interesting entertainment. Two persons placed themselves, back to back, opposite two large concave mirrors of brass, when, upon one of them speaking in a whisper, with his lips in the focus, as seen by *Fig.* 180, the sound would pass from his mouth to the mirror near, and thence

FIG. 180.



Reflection by Mirrors.

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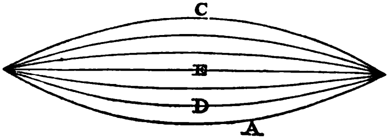
717. When an echo repeats seven syllables, how far off is the reflecting surface? Explain this. 718. How many syllables is it said some echoes repeat? 719. Why is it that persons can converse on the opposite sides of a river, when they could not hear each other at the same distance over the land? Explain Fig. 180, and show why a sound may be heard only at two points.

be reflected back in parallel lines to the opposite distant mirror, and then the whisper, reaching the focus of that mirror, would be distinctly heard by the other person, with his ear in the focus. The singular and curious part of this exhibition is, that a person standing any where between the mirrors, but out of the focus, would not be aware of any sound whatever.

720. Musical Instruments.—*The strings of musical instruments are elastic cords, which being fixed at each end, produce sounds by vibrating in the middle.*

The string of a *violin* or *piano*, when pulled to one side by its middle and let go, vibrates backward and forward, like a pendulum, and striking rapidly against the air, produces tones, which are grave, or acute, according to its tension, size, or length.

FIG. 181.



Musical String.

721. The manner in which such a string vibrates is shown by *Fig.* 181. If pulled from E to A, it will not stop again at E; but, in passing from A to E, it will gain a momentum which will carry it to C, and, in returning, its momentum will again carry it to D, and so on, backward and forward, like a pendulum, until its tension and the resistance of the air will finally bring it to rest.

722. *Tones depend on Size and Tension.*—The grave or sharp tones of the same string depend on its different degrees of tension; hence, if a string be struck, and, while vibrating, its tension be increased, its tone will be changed from a lower to a higher pitch.

Strings of the same length are made to vibrate slow, or quick, and consequently to produce a variety of sounds, by making some larger than others, and giving them different degrees of tension. The *violin* and *bass viol* are familiar examples of this. The low, or bass strings, are covered with metallic wire, in order to make their magnitude and weight prevent their vibration from being too rapid, and thus they are made to give deep or grave tones. The other strings are diminished in thickness, and increased in tension, so as to make them produce a greater number of vibrations in a given time, and thus their tones become sharp or acute in proportion.

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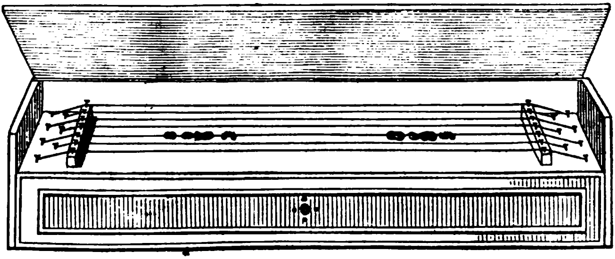
720. How do the strings of musical instruments produce sounds? 721. Explain Fig. 181. 722. On what do the grave or acute tones of the same string depend? Why are the bass strings of instruments covered with metallic wire?

723. **Æolian Harp.**—Under certain circumstances, a long string will divide itself into halves, thirds, or quarters, without depressing any part of it, and thus give several harmonious tones at the same time.

The fairy tones of the Æolian harp, *Fig.* 182, are produced in this manner. This instrument consists of a simple box of wood, with four or five strings, two or three feet long, fastened at each end. These are tuned in unison, so that when made to vibrate with force, they produce the same tones. But when suspended in a gentle breeze, each string, according to the manner or force in which it receives the blast, either sounds, as a whole, or is divided into several parts, as above described. The result of which, is the production of the most pleasing combination and succession of sounds, that the ear ever listened to or fancy perhaps conceived. After a pause, this fairy harp is often heard beginning with a low and solemn note, like the bass of distant music in the sky; the sound then swells as if approaching, and other tones break forth, mingling with the first, and with each other.

FIG. 182.



Æolian Harp.

724. The manner in which a string vibrates in parts, will be understood by *Fig.* 183.

Suppose the whole length of the string to be from A to B, and that it is fixed at these two points. The portion from B to C, vibrates as though it was fixed at C, and its tone differs from those of the other parts of the string. The same happens from C to D, and from D to A. While a string is thus vibrating, if a small piece of paper be laid on the part C, or D, it

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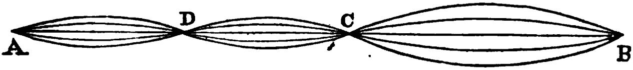
723. Why is there a variety of tones in the Æolian harp, since all the strings are tuned in unison? 724. Explain Fig. 182, showing the manner in which strings vibrate in parts.

FIG. 183.

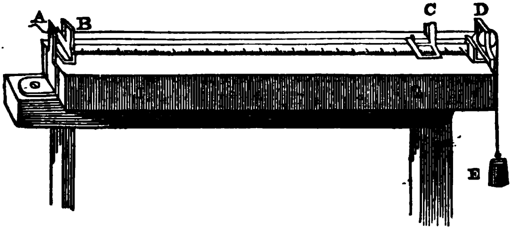


Æolian Harp.

will remain, but if placed on any other part of the string, it will be shaken off.

725. MONOCHORD.—An instrument called *monochord* "single string," or *sonometer* "sound measurer," is used to determine the number and theory of musical vibrations, as applied to stringed instruments. It consists of a wooden box, several feet in length, 1, 2, *Fig.* 184. At A, a catgut or metallic string is fastened, which passing over the bridges, B and C, and then over the roller, D, has a weight suspended for its tension at E.

FIG. 184.



Monochord.

The bridge, C, is attached to a scale, on which it moves, so that the string can be shortened at pleasure. There is also provided a number of leaden weights, having slits to the center, to be slipped on the string, and by which its tension can be in creased or diminished.

726. By means of the monochord, many curious and important inferences, with respect to stringed instruments have been drawn. We extract from Muller a few of the most important of these laws.

727. *The number of vibrations of a string, is inversely as its length.*

If the string of any instrument makes a given number of vibrations in a certain time, it would make in the same time, 2,

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725. What is the meaning of monochord, and what its use? Describe the monochord.
727. To what is the number of vibrations of a string proportioned?

3, or 4 times as many vibrations, if, with the same tension, we let only $\frac{1}{2}$, $\frac{1}{3}$, or $\frac{1}{4}$ of its length vibrate, and so in these proportions, whether it be made longer or shorter.

728. *The number of vibrations of a string is proportional to the square root of its stretching weight, or its tension.*

Thus, if the tension of a given length of string be equal to 4, 9, or 16, then the velocity of its vibrations will be 2, 3, or 4 times as great.

729. *The number of vibrations of different strings, of the same substance, is inversely as their thickness.*

If we take two steel wires of equal length, whose diameters are as 1 and 2, then with the same tension, 1 will make twice as many vibrations as 2 in the same time.

730. *Capacity of the Human Ear.*—From Prof. Hoblyn's, London edition of this work, we add the following: "The capacity of the human ear for appreciating the vibrations of a sonorous body, is restricted within certain limits. It has been proved by experiment, that the lowest note we are capable of perceiving, is that produced by a body performing 32 half vibrations, or 16 impulses, in one second of time; and the highest, that which is performed by 16,000 impulses in the same time. It is stated, however, that a finely attuned ear is capable of appreciating, as a distinct sound, a kind of hissing noise, occasioned by 48,000 half vibrations, or 24,000 impulses in a second of time."

WIND INSTRUMENTS.

731. In stringed instruments, we have seen that the sounds are produced by the vibration of stretched cords on the air.

In musical pipes the tones are produced, in part, by the passage of the air through apertures of various forms, and in part by the vibration of the pipes themselves.

732. *Organ Pipes.*—The most complicated, important, and costly instrument is the organ. This, indeed, embraces in its structure, nearly every known wind instrument, and therefore, may be considered as a collection of such instruments, each of which may be played separately, or, when great power is required, several may be played in unison.

733. *Stops.*—A stop consists of a rank of pipes on a uniform model. Some are only treble, and others only bass stops. In

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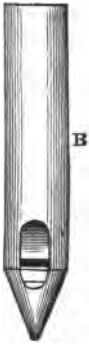
728. How does tension affect the vibrations? **729.** How does thickness affect vibrations? **730.** What is said of the capacity of the ear to appreciate sounds? **731.** How are the tones in the musical pipes produced? **732.** What instruments does the organ embrace? **733.** What is meant by a stop?

general, however, a stop includes the pipes belonging to each instrument, as the Flute, Trumpet, Hautboy, and Dulciana stops.

FIG. 185



Flue Pipe

734. The *Diapason* (which means through all) is the principal stop, and on this all the other stops are founded, or are made to correspond.

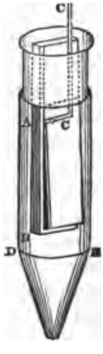
735. *Flue and Reed Stops.*—This is the great division of the whole organ, and depends on the mechanism by which the tones are produced, every organ in this respect, having only two stops, or sorts of pipes, however numerous the individual stops may be.

736. *Flue Pipes.*—These consist of the body or tube, B, *Fig.* 185, and the foot, P, between which there is a diaphragm or partition, having a narrow, transverse aperture to emit the wind from the bellows, as shown by the figure. Over this aperture is a sharp edge called the *upper* lip, against which the wind is forced, and by which the sound is produced, and which is modified by the size and form of the pipe.

737. *Chestnut Whistle.*—The chestnut or willow whistle, made by every lad in the country, is a good illustration of the flue organ pipe, the construction of both, being precisely on the same principle.

738. *Reed Pipes.*—These differ from the above, in having a piece of thin brass, or other metal, placed in the mouth of the pipe, and called the *tongue*, the vibration of which produces the sound. The tongue is fastened to a cylindrical piece of metal between C C, *Fig.* 186, which is called the *block*. The dotted lines C C, show the *tuning wire*, which passes through the block, and by the sliding of which, up and down, the tones are varied, the pitch becoming flat or sharp, as the tongue is made long or short.

FIG. 186.



Reed Pipe.

The reed pipes are generally of metal, the body of which is shown by A B.

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734. What is said of the diapason stop? 735. Into what stops is the entire organ divided? 736. Show by Fig. 185, the construction of the flue pipes. 737. What is said to be a good illustration of these pipes? 738. Describe the parts of a reed pipe by Fig. 186.

739 *Structure of the Pipes.*—The large pipes are commonly made of wood, and are square in form, though some wood pipes are only a few inches long. The largest of these pipes are 32 feet long and 15 inches in diameter.

740. The metal pipes are in the form of a cone or cylinder, most of the smaller ones being of these forms and substance. In a few instances, metallic pipes of immense size and weight have been constructed.

The largest ever made, is at Birmingham, England, which is 32 feet long and 24 inches in diameter. It is of zinc, in form of a cylinder, standing in front of all the other pipes.

741. *Tuning the Organ.*—The pipes are tuned by various means, depending on their forms; the substance of which they are made, and whether they are open or stopped.

742. *Stopped wooden* pipes are tuned by a pompion, or stopper, which is of wood, covered with leather, exactly fitting the end, and which is drawn up, or pushed down, to make the tones more grave or sharp.

The *stopped metal* pipes, have a cap on the top, and by the movement of which, they are tuned on the same principle as those of wood. In some cases, stopped metallic pipes are tuned by means of *ears* on each side of the mouth, by the bending of which, the tones are varied.

Open metal pipes are tuned by a wooden instrument, one end of which is a solid cone, and the other a hollow cone. By this, the tops of the pipes are expanded by introducing the solid end, to make the pitch *sharper*, and contracted by the hollow cone, to make the pitch *flatter*.

The *reed* pipes, as already noticed, are tuned by the motions of the tuning wire.

Reed Pipes vary with the Temperature.—The tongues of these pipes vary in length by heat and cold, and hence their tones change, for the same reason that the clock goes faster in winter than in summer, as explained, 283. It is probably on this account that organists find difficulty in keeping these stops in tune.

743. ANTIQUITY OF THE ORGAN.—The earliest account of any instrument similar to the organ, occurs in the Tenth Book of Vitruvius, a Greek writer, who lived a century before the Christian era. This was moved by water, and hence was called a *hydraulicon.*

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739. What is said of the structure of these pipes ? 740. Of what size are the largest organ pipes ? 741. How are the pipes tuned ? 742. How are the stopped pipes tuned ? How are the open pipes tuned ? What is said of the influence of temperature on the reed pipes ? 743. What is said of the antiquity of the organ ?

The first organ spoken of in France, was of Greek construction, and was sent to *King Pepin*, the father of Charlemagne, by the Emperor Constantine, about A. D. 757. This was moved by wind.

The first of any size known in England, was that of Winchester Cathedral, in 951. This had 26 pairs of bellows, which it required 70 men to work. It had 10 keys, and 40 pipes to each key.

Notwithstanding the antiquity of this invention, it was not until after the Reformation that any great improvements were made in this instrument. Even so late as 1660, only four organ builders were to be found in Great Britain.

This instrument, in our country, was unknown to the common people a century ago; and at the time of our revolution, comparatively few persons, except in large cities, had ever heard an organ. It is hardly necessary to add, that the organ, as it now exists, is an entirely different instrument from that so called only fifty years ago, and that, at present, no village having a church of any pretensions, is without an organ.

LARGE ORGANS.

744. Perhaps we can not gratify our readers. more than to add short notices of a few of the largest organs in the world.

Haarlem Organ.—This has long been the most celebrated of organs. It was built in 1638, at the cost of $60,000. The case is 108 feet high by 50 feet wide. It has 60 stops; 12 pair of bellows; 4 rows of keys; 5,000 pipes, of which two are 32 feet long and 15 inches wide. The fee for hearing the whole is $5.

Freyburg Organ, in Switzerland.—It is said that no instrument ever was, or ever will be built like this; the artist, Moser, refusing to build another, and no one being allowed to see the interior. The wonder, and the secret, with respect to this organ, is in its having a stop, the tones of which are so exactly like those of the human voice, that visitors mistake it for a large choir of singers. It has 68 stops and 4 rows of keys.

Music Hall, Edinburgh, Organ.—This immense instrument has 82 stops, 4 rows of keys, 1 wooden pipe of 32 feet, and several of metal of 16 feet in length.

Hamburgh Organ.—This organ, in St. Michael's Church, was built in 1762, and cost more than $20,000. It has 4 rows of keys; three pipes of 32 feet, and nine of 16 feet; 10 wind chests, and 10 pair of bellows. The pipes of the large pedal stop are of pure tin, highly polished, and placed in front.

The Weingarten Organ.—This is in the Benedictine Monastery, in Suabia, and was built about 1750. It has 4 rows of keys, 3 pipes of 32 feet, 4 of 16 feet, and 4 unisons. It has, in the whole, 6,666 pipes; namely, in the *great organ*, 2,176; in the *choir*, 1,176; in the *third organ*, 1,274; in the *echo organ*, 1,225; and in the *pedal organ*, 815.

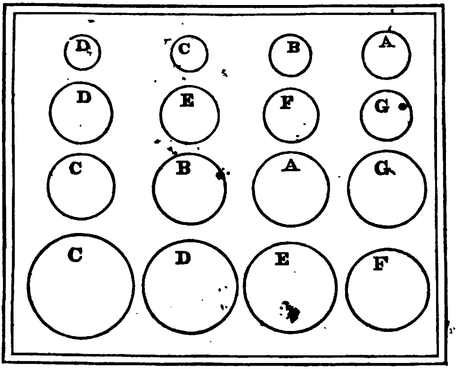
Berlin Organ.—This organ, at Berlin, Prussia, was designed to be the largest in the world, and to contain 150 stops, and 6 rows of keys, besides the pedals, but it remains unfinished.

Baltimore Cathedral Organ.—This is said to be the largest in the United States. It has 36 stops and 2,213 pipes, the largest being 32 feet long.

HARMONICON.

This is a musical instrument invented by Dr. Franklin, though it has been much improved since his day.

FIG. 187.



Harmonicon.

It consists of a number of glass goblets of different sizes, and so attuned to each other as to form the hormonic scale.

They are firmly fastened to the bottom of a box, their tones being so nicely adapted to the scale, by the artist who constructs them, as to need no tuning, though one or two of them contain water as a convenience.

They are played by touching the edges with the wet finger, and their tones may be prolonged, and made to swell or diminish, like those of the violin.

Perhaps no music, to which the human ear has ever listened, is equal in sweetness, delicacy, and smoothness, to this. No one can hear it without a thrill of delight, nor, for the first time, without astonishment. It is, indeed, an Æolian harp under command of the artist.

The arrangement and comparative sizes of the goblets are shown by *Fig.* 187, which presents the natural key, or C major.

The goblets hold from a quart to half-a-pint, and their tones depend, in part, upon their capacity, and, in part, upon the weight or thickness.

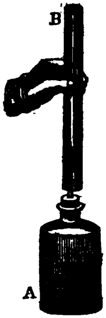
The instrument here represented, is capable of producing all the tones of the most common and simple melodies.

We are told that Mr. Francis H. Smith, of Baltimore, furnishes Harmonicons, put up in boxes, at various prices, from 18 to 85 dollars.

BURNING OF HYDROGEN.

745. When a jet of hydrogen, passing through a minute orifice, is burned, and a glass tube of an inch or more, *Fig.* 188, in diameter, is held so as to include it, musical tones of the most suprising sweetness are produced, and may be varied by moving the tube up and down, so as to become, at pleasure, so low and soft as hardly to be heard, and then, again, so loud as to be heard in all directions. In reference to these tones, a lover of music says: "In truth, the air of the apartment is, as it were, filled with divine discourse, and, in wonderment, the eyes search all around for the cause and part from whence issue these sweet sounds."

FIG. 188.



Hydrogen Burner

ATMOSPHERIC PHENOMENA.

746. The term *atmosphere* is from two Greek words, which signify *vapor* and *sphere*. It is the air which surrounds the earth to the height of forty-five miles, and is essential to the lives of all animals, and the production of all vegetables.

All meteorological phenomena, with which we are acquainted,

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746. What is the atmosphere? How high does the atmosphere extend? What phenomena mentioned depend on the atmosphere?

depend chiefly, if not entirely, on the influence of the atmosphere. Fogs, winds, rain, dew, hail, snow, thunder, lightning, electricity, sound, and a variety of other phenomena of daily occurrence, belong to the atmosphere. We have, however, only room for the most common result of atmospheric changes. *Wind and Rain.*

WIND.

447. *Wind is nothing more than air in motion. The use of a fan in warm weather only serves to move the air, and thus to make a little breeze about the person using it.*

As a natural phenomenon, that motion of the air which we call wind, is produced in consequence of there being a greater degree of heat in one place than in another. The air thus heated, rises upward, while, that which surrounds this, moves forward to restore the equilibrium.

The truth of this is illustrated by the fact that, during the burning of a house in a calm night, the motion of the air toward the place where it is thus rarefied, makes the wind blow from every point toward the flame.

748. *Sea and Land Breeze.*—On islands, situated in hot climates, this principle is charmingly illustrated. The land, during the day-time, being under the rays of a tropical sun, becomes heated in a greater degree than the surrounding ocean, and, consequently, there rises from the land a stream of warm air, during the day, while the cooler air from the surface of the water, moving forward to supply this partial vacancy, produces, a cool breeze setting inland on all sides of the island. This constitutes the *sea breeze*, which is so delightful to the inhabitants of those hot countries, and, without which, men could hardly exist in some of the most luxuriant islands between the tropics.

During the night, the motion of the air is reversed, because the earth, being heated superficially, soon cools when the sun is absent, while the water, being warmed several feet below its surface, retains its heat longer.

Consequently, toward morning, the earth becomes colder than the water, and the air, sinking down upon it, seeks an equilibrium, by flowing outward, like rays from a center, and, thus, the *land breeze* is produced.

The wind then continues to blow from the land until the

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747. What is wind? As a natural phenomenon, how is wind produced; or, what is the cause of wind? How is this illustrated? 748. In the islands of hot climates, why does the wind blow inland during the day, and off the land during the night? What are these breezes called?

equilibrium is restored, or until the morning sun makes the land of the same temperature as the water, when, for a time, there will be a dead calm. Then, again, the land becoming warmer than the water, the sea breeze returns, as before; and, thus, the inhabitants of those sultry climates are constantly refreshed, during the summer season, with alternate land and sea breezes.

749. Trade Winds.—*At the equator, which is a part of the earth continually under the heat of a burning sun, the air is expanded, and ascends upward, so as to produce currents from the north and south, which move forward to supply the place of the heated air as it rises.*

These two currents, coming from latitudes where the daily motion of the earth is less than at the equator, do not obtain its full rate of motion, and, therefore, when they approach the equator, do not move so fast eastward as that portion of the earth, by the difference between the equator's velocity, and that of the latitudes from which they come. This wind, therefore, falls behind the earth in her diurnal motion, and consequently has a relative motion toward the west. This constant breeze toward the west is called the *trade-wind*, because a large portion of the commerce of nations comes within its influence.

FIG. 189.

750. *Counter Currents.*—While the air in the lower regions of the atmosphere is thus constantly flowing from the north and south toward the equator, and forming the trade-winds between the tropics, the heated air from these regions as perpetually rises, and forms a counter current through the higher regions, toward the north and south, from the tropics, thus restoring the equilibrium.

751. *Illustration by a Door.*—This counter motion of the air in the upper and lower regions, is illustrated by a very simple experiment. Open a door a few inches, leading into a heated room, and hold a lighted candle at the top of the passage; the

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749. What is said of the ascent of heated air at the equator? What is the consequence on the air toward the north and south? How are the trade-winds formed? 750. While the air in the lower regions flows from the north and south toward the equator, in what direction does it flow in the higher regions? 751. How is this counter current in lower and upper regions illustrated by a simple experiment?

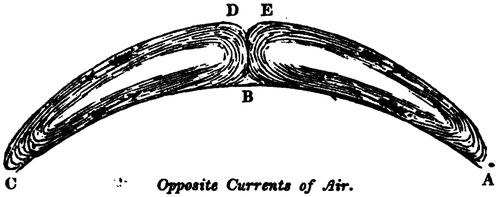
current of air, as indicated by the direction of the flame, will be *out* of the room. Then, set the candle on the floor, and it will show that the current is there *into* the room. Thus, while the heated air rises and passes out of the room, at the same time, that which is colder flows in, along the floor, to take its place. See *Fig.* 189.

This explains the reason why our feet are apt to suffer with the cold, in a room moderately heated, while the other parts of the body are comfortable. It also explains why those who sit in the gallery of a church are sufficiently warm, while those who sit below may be shivering with the cold.

752. From such facts, showing the tendency of heated air to ascend, while that which is colder moves forward to supply its place, it is easy to account for the reason why the wind blows perpetually from the north and south toward the tropics; for, the air being heated, as stated above, it ascends, and then flows north and south, toward the poles, until, growing cold, it sinks down, and again flows toward the equator.

Perhaps these opposite motions of the two currents will be better understood by the sketch, *Fig.* 190.

FIG. 190.



Opposite Currents of Air.

Suppose A B C to represent a portion of the earth's surface, A being toward the north pole, C toward the south pole, and B, the equator. The currents of air are supposed to pass in the direction of the arrows. The wind, therefore, from A to B, would blow on the surface of the earth, from north to south, while, from E to A, the upper current would pass from south to north, until it came to A, when it would change its direction toward the south. The currents in the southern hemisphere, being governed by the same laws, would assume similar directions.

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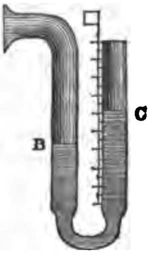
752. What common fact does this experiment illustrate? Explain Fig. 190, and show which way the air passes.

VELOCITY OF WIND.

753. The velocity of aërial movements amount, according to authors, from 0 to upwards of 100 miles an hour; but, the maximum is variously stated by different experiments, nor do we see how any great degree of accuracy can be attained on this point. The best method is to deduce the velocity by the force of wind; which is done by an instrument invented for that purpose by Dr. Lind, a figure of which we here insert.

754. **Anemometer, or Wind Measurer.**—It consists of a glass tube, *Fig.* 191, bent into the form of the letter U, and open at both ends. The upper end of B is bent to the horizontal direction, and is widened at the mouth for the purpose of receiving the wind. The tube being partly filled with water, and exposed to a current of air, the fluid is depressed in that, and of course rises in the other leg of the tube. As the water is on a level in both branches when the air is still, if it is depressed to B on one side, it must rise to C on the other, the amount of rise, and consequently the degree of force, being measured by a graduated scale. Now, as the pressure of water is as its height, the rise in the tube will not be in direct proportion to the force of the wind, but the velocity of the wind will be in the ratio of the square root of the resistance. The tube is diminished at the base to check the undulations of the water.

FIG. 191.



Anemometer.

755. By this instrument it is found that the following popular expressions with respect to aërial currents, are indicated on the scale as here expressed.

Velocity of the Wind in miles per hour.	Com. appellation of the force of Wind.
1	Hardly perceptible.
4	Gentle breeze.
6	Pleasant wind.
10	Brisk wind.
15	Very brisk wind.
20	High wind.
30	Very high wind.
40	A storm.
50	A hard storm.

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754. What is the name of the instrument which measures the force of wind? How is it constructed?

60	A great storm.
80	A hurricane.
100	A violent hurricane.

RAIN.

756. *Rain is falling water in the form of drops. It appears to result from the meeting of two clouds of different temperatures.*

In explaining the theory of rain, it must be understood that warm air has a greater capacity for moisture than cold. It is also ascertained that this capacity increases at a much faster ratio than the increase of temperature itself; and, hence, it follows, that if two clouds, at different temperatures, completely saturated, meet and mingle together, a precipitation of moisture must take place in consequence of the mixture. This would result from the fact that the warmest cloud contained a greater portion of moisture than is indicated by its temperature, as stated above, while the mixture would form a mean temperature, but the mean quantity of vapor could not be retained, since the sum of their capacities for vapor would thus be diminished.

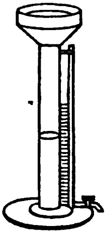
757. Suppose for example, that at the temperature of 15 degrees, air can hold 200 parts of moisture; then at 30 degrees it would hold 400 parts, and at 45 degrees 800 parts. Now let two equal bulks of this air, one at 15, and the other at 45 degrees be mixed, the compound would then contain 200 and 800 parts of moisture=1,000, that is, 500 each, and the temperature of the mixture would be 30 degrees. But at this temperature, air is saturated with 400 parts of vapor, therefore, 100 parts is rejected and falls in the form of rain.

This is Dr. Hutton's theory of rain, and observation has seemed to prove its truth.

758. Rain Gauge.—This is an instrument designed to measure the quantity of rain which falls at any given time and place.

759. A variety of forms, some quite complicated, have been invented for this purpose. The most simple and convenient, for common purposes, is that represented by *Fig.* 192. It may be two feet high, round in form, and made of tin, or copper, well painted. It is

FIG. 192.



Rain Guage.

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755. What correspondence is there between the velocity of wind and common expressions? 756. What is rain? What is said of the ratio of capacity for moisture increasing faster than the temperature in clouds? Explain the reason why, when two clouds meet of different temperatures, rain is the result? 758. What is the design of the rain gauge? What are the forms and materials of this instrument? 759. Describe the scale, and what it indicates with respect to the size of the funnel and cylinder?

furnished with a small metallic faucet for drawing off the water, and into the stem of this, is inserted a glass tube, as a scale, divided into inches and tenths of inches. This may be done by means of paper, pasted on and then varnished.

The water will stand at the same height in the glass scale that it does in the cylinder, and, being on the outside, the quantity may be known at a glance. If the funnel, or top, is twice the size of the cylinder, then, an inch in the scale will indicate half an inch received into the guage, or these proportions may be a tenth, when much accuracy is required.

760. Quantity of rain which falls annually in different counries in inches.

Lisbon,	25	inches.	Bergen,	85	inches.
Dover,	44	“	Stockholm,	19	“
London,	23	“	Petersburgh,	17	“
Paris,	21	“	Genoa,	44	“
Ratisbon,	21	“	Rome,	29	“

Muller, who is our authority for the above, says that in Southern Europe, the annual number of rainy days averages 120. In Central Europe this number is 146, and in Northern Europe it is 180. The number of rainy days, as well as the quantity which falls, diminishes with increased distance from the sea.

CHAPTER XI.

OPTICS.

1. *This term, derived from the Greek, signifies seeing, or to see. It is that science which treats of vision, and the laws, properties, and phenomena of light.*

2. It admits of two divisions, viz., *Dioptrics*, or a discourse on the laws of refracted light, and *Catoptrics*, a treatise on reflected light.

This science involves some of the most elegant and important branches of natural philosophy. It presents us with experiments which are attractive by their beauty, and which astonish us by their novelty; and, at the same time, it investigates the

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1. What is the meaning of optics? 2. What are the meaning of dioptrics and catoptrics? What is said of the elegance and importance of this science?

principles of some of the most useful among the articles of common life.

3. There are two opinions concerning the nature of light. Some maintain that it is composed of material particles, which are constantly thrown off from the luminous body; while others suppose that it is a fluid, diffused through all nature, and that the luminous, or burning body, occasions waves or undulations in this fluid, by which the light is propagated in the same manner as sound is conveyed through the air.

4. The most probable opinion, however, is that light is composed of exceedingly minute particles of matter. But whatever may be the nature or cause of light, it has certain general properties or effects which we can investigate. Thus, by experiment, we can determine the laws by which it is governed in its passage through different transparent substances, and also those by which it is governed when it strikes a substance through which it can not pass. We can likewise test its nature to a certain degree, by decomposing or dividing it into its elementary parts, as the chemist decomposes any substance he wishes to analyze.

DEFINITIONS.

5. To understand the science of optics, it is necessary to define several terms, which, although some of them may be in common use, have a technical meaning, when applied to this science.

Light is that principle, or substance, which enables us to see any body from which it proceeds. If a luminous substance, as a burning candle, be carried into a dark room, the objects in the room become visible, because they reflect the light of the candle to our eyes.

6. *Luminous* bodies are such as emit light from their own substance. The sun, fire, and phosphorus are luminous bodies. The moon, and the other planets, are not luminous, since they borrow their light from the sun.

7. *Transparent* bodies are such as permit the rays of light to pass freely through them. Air, and some of the gasses are perfectly transparent, since they transmit light without being visible themselves. Glass and water are also considered transparent, but they are not perfectly so, since they are themselves visible,

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3. What are the two opinions concerning the nature of light? 4. What is the most probable opinion? 5. What is light? 6. What is a luminous body? 7. What is a transparent body? Are glass and water perfectly transparent? How is it proved that air is perfectly transparent?

and therefore do not suffer the light to pass through them without interruption.

8. *Translucent* bodies are such as permit the light to pass, but not in sufficient quantity to render objects distinct, when seen through them.

9. *Opaque* is the reverse of transparent. Any body which permits none of the rays of light to pass through it, is opaque.

10. *Illuminated*, enlightened. Any thing is illuminated when the light shines upon it so as to make it visible. Every object exposed to the sun is illuminated. A lamp illuminates a room, and every thing in it.

A *Ray* is a single line of light, as it comes from a luminous body.

A *Beam* of light is a body of parallel rays.

A *Pencil* of light is a body of diverging or converging rays.

Divergent rays are such as come from a point, and continually separate wider apart as they proceed.

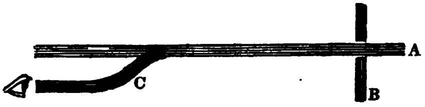
Convergent rays are those which approach each other, so as to meet at a common point.

Luminous bodies emit rays, or pencils of light, in every direction, so that the space through which they are visible, is filled with them at every possible point.

Thus, the sun illuminates every point of space within the whole solar system. A light, as that of a light-house, which can be seen from the distance of ten miles in one direction, fills every point in a circuit of ten miles from it, with light. Were this not the case, the light from it could not be seen from every point within that circumference.

11. *Motion of light. The rays of light move forward in straight lines from the luminous body, and are never turned out of their course, except by some obstacle.*

FIG. 193.



Motion of Light.

Let A, *Fig.* 193, be a beam of light from the sun, passing

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8. What are translucent bodies? 9. What are opaque bodies? 10. What is meant by illuminated? What is a ray of light? What is a beam? What a pencil? What are divergent rays? What are convergent rays? In what direction do luminous bodies emit light? How is it proved that a luminous body fills every point within a certain distance with light? 11. Why can not a beam be seen through a bent tube?

through a small orifice in the window shutter, B. The sun can not be seen through the crooked tube, C, because the beam passing in a straight line, strikes the side of the tube, and therefore does not pass through it.

12. All illuminated bodies, whether natural or artificial, throw off light in every direction of the same color as themselves, though the light with which they are illuminated is white or without color.

This fact is obvious to all who are endowed with sight. Thus the light proceeding from grass is green, while that proceeding from a rose is red, and so of every other color.

We shall be convinced in another place, that the white light with which things are illuminated, is really composed of several colors, and that bodies reflect only the rays of their own color, while they absorb all the other rays.

13. *Velocity of Light.*—Light moves with the amazing rapidity of about 95 millions of miles in 8½ minutes, since it is proved by certain astronomical observations, that the light of the sun comes to the earth in that time. This velocity is so great, that to any distance at which an artificial light can be seen, it seems to be transmitted instantaneously.

If a ton of gun-powder were exploded on the top of a mountain, where its light could be seen a hundred miles, no perceptible difference would be observed in the time of its appearance on the spot, and at the distance of a hundred miles.

DIOPTRICS, OR THE REFRACTION OF LIGHT.

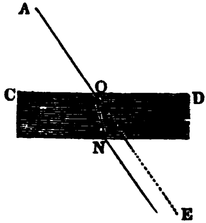
14. *Although a ray of light will pass in a straight line, when not interrupted, yet when it passes obliquely from one transparent body into another, of a different density, it leaves its linear direction, and is bent, or refracted more or less, out of its former course.*

This change in the direction of light, seems to arise from a certain power, or quality, which transparent bodies possess in different degrees; for some substances bend the rays of light much more obliquely than others

The manner in which the rays of light are refracted, may be readily understood by *Fig.* 194.

Let A be a ray of the sun's light, proceeding obliquely toward the surface of the water, C D, and let E be

FIG. 194.

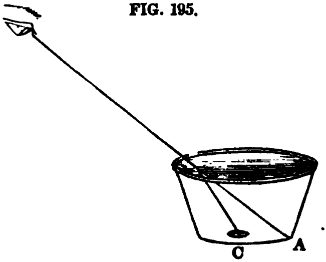


Refraction.

the point which it would strike, if moving only through the air. Now, instead of passing through the water in the line, A E, it will be bent or refracted, on entering the water, from O to N, and having passed through the fluid it is again refracted in a contrary direction on passing out of the water, and then proceeds onward in a straight line as before.

15. *Cup and Shilling.*—The refraction of water is beautifully proved by the following simple experiment. Place an empty cup, *Fig.* 195, with a shilling on the bottom, in such a position that the side of the cup will just hide the piece of money from the eye. Then let another person fill the cup with water, keeping the eye in the same position as before. As the water is poured in, the shilling will become visible, appearing to rise with the water. The effect of the water is to bend the ray of light coming from the shilling, so as to make it meet the eye below the point where it otherwise would. Thus the eye could not see the shilling in the direction of C, since the line of vision toward A and C, is hidden by the side of the cup. But the refraction of the water bends the ray downward, producing the same effect as though the object had been raised upward, and hence it becomes visible.

FIG. 195.



Cup and Shilling

16. *Refraction by several Media.*—Any transparent body through which light passes, is called a *medium*, and it is found in all cases, "*that where a ray of light passes obliquely from one medium into another of a different density, it is refracted, or turned out of its former course.*" This is illustrated in the above examples, the water being a more dense medium than air. The refraction takes place at the surface of the medium, and the ray is refracted in its passage *out* of the refracting substance as well as *into* it.

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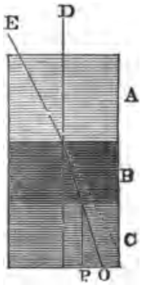
12. What is the color of the light which different bodies throw off? If grass throws off green light, what becomes of the other rays? 13. What is the rate of velocity with which light moves? Can we perceive any difference in the time which it takes an artificial light to pass to us from a great or small distance? 14. What is meant by the refraction of light? Do all transparent bodies refract light equally? Explain Fig. 194, and show how the ray is refracted in passing into, and out of the water. 15. Explain Fig. 195, and state the reason why the shilling seems to be raised up by pouring in the water. 16. What is a medium? In what direction must a ray of light pass from one medium to another to be refracted?

17. If the ray, after having passed through the water, then strikes upon a still more dense medium, as a pane of glass, it will again be refracted. It is understood, that in all cases, the ray must fall upon the refracting medium obliquely, in order to be refracted, for if it proceeds from one medium to another perpendicularly to their surfaces, it will pass straight through them all, and no refraction will take place.

18. Thus, in *Fig.* 196, let A represent air, B, water, and C, a piece of glass. The ray, D, striking each medium in a perpendicular direction, passes through them all in a straight line. The oblique ray passes through the air in the direction of C, but meeting the water, is refracted in the direction of O; then falling upon the glass, it is again refracted in the direction of P, nearly parallel with the perpendicular line, D.

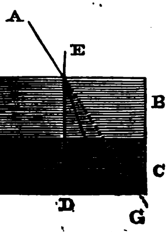
19. *In all cases where the ray passes out of a rarer into a denser medium, it is refracted toward a perpendicular line, raised from the surface of the denser medium, and so, when it passes out of a denser, into a rarer medium, it is refracted from the same perpendicular.*

FIG. 196.



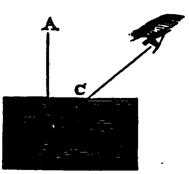
Air, Water, and Glass.

FIG. 197.



Glass and Water.

FIG. 198.



Water

Let the medium, B, *Fig.* 197, be glass, and the medium, C, water. The ray, A, as it falls upon the medium, B, is refracted toward the perpendicular line, E D; but when it enters the water, whose refractive power is less than that of glass, it is not bent so near the perpendicular as before, and hence it is refracted *from*, instead of toward the perpendicular line, and

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17. Will a ray falling perpendicularly on a medium be refracted? 18. Explain Fig. 196, and show how the ray, E, is refracted. 19. When it passes out of a rarer into a denser medium, in what direction is it refracted? When it passes out of a denser into a rarer medium, in what direction is the refraction? Explain this by Fig. 197

approaches the original direction of the ray, A G, when passing through the air.

20. The cause of refraction appears to be the power of attraction, which the denser medium exerts on the passing ray; and in all cases the attracting force acts in the direction of a perpendicular to the refracting surface.

21. *Refraction by Water.*—The refraction of the rays of light, as they fall upon the surface of the water, is the reason why a straight rod, with one end in the water, and the other end rising above it, appears to be broken, or bent, and also to be shortened.

Suppose the rod, A, *Fig.* 198, to be set with one half of its length below the surface of the water, and the other half above it. The eye being placed in an oblique direction, will see the lower end apparently at the point, O, while the real termination of the rod would be at N; the refraction will therefore make the rod appear shorter by the distance from O to N, or one-fourth shorter than the part below the water really is. The reason why the rod appears distorted, or broken, is, that we judge of the direction of the part which is under the water, by that which is above it, and the refraction of the rays coming from below the surface of the water, give them a different direction, when compared with those coming from that part of the rod which is above it, Hence, when the whole rod is below the water, no such distorted appearance is observed, because then all the rays are refracted equally,

For the reason just explained, persons are often deceived in respect to the depth of water, the refraction making it appear much more shallow than it really is; and there is no doubt but the most serious accidents have often happened to those who have gone into the water under such deception; for a pond which is really six feet deep, will appear to the eye only a little more than four feet deep.

TWILIGHT PRODUCED BY ATMOSPHERIC REFRACTION.

22. The illumination of the heavens, which takes place before the rising, and after the setting of the sun, and called *twilight*, prolongs the day about two hours. This is produced by the refraction of the sun's rays by the atmosphere. The refractive power being in proportion to the density of the atmosphere,

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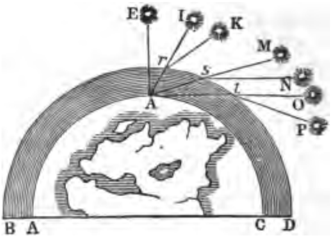
20. What is the cause of refraction? 21. What is the reason that a rod, with one end in the water, appears distorted and shorter than it really is? Why does the water in a pond appear less deep than it really is?

FIG. 199.



increases as the sun approaches the horizon, so that it is often the case, in a clear evening, the setting sun appears of an oval form, in consequence of the lower limb being so much more highly refracted than the upper.

23. This subject will be understood by the following explanation of *Fig.* 199, where A C represents one half of our globe, and B D the atmosphere by which it is surrounded. As already explained, when the rays of light pass directly through any medium there is no refraction, and hence a person sitting at A, and seeing the sun at the zenith, E, would see him where he really is. But about 2 o'clock in the afternoon, the person at A, would see the sun at I, though in reality he would be at K, 33 seconds below his apparent situation. At 4 o'clock the sun would appear at M, when really he is at N, and at 6 o'clock, when he seems to be sitting, he will seem to be at O, though at that time he will really be at P, more than 32 minutes below the horizon. These phenomena, arising from the different refractive powers of the atmosphere, are only known to those who have taken the pains to study the nature of causes and effects in and about the world he inhabits.

DOUBLE REFRACTION.

24. *By double refraction is meant that property in certain native minerals, by which they transmit two images of a single object.*

This property is most perfect in specimens of carbonate of lime, usually called Iceland spar; the latter name being formerly given to the fine specimens from that country. At present these rhomboids are found in most primitive limestone countries.

REFRACTION

A perfect piece, two inches in diameter, will show the lines about a quarter of an inch apart, the greater the thickness the

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23. Explain by Fig. 199, why we see the sun in false directions. 24. What is meant by double refraction? Explain its cause.

more distant will be the images presented. Sometimes two or three pieces of different sizes, are wanted by the experimenters.

If a piece of this spar be laid over a black line, and then be made to revolve slowly, it will be observed that the doubly refractive power increases in proportion as the acute angles of the rhomb correspond to the direction of the line, when the refraction is greatest, or the two lines are widest apart. On the contrary, if the crystal is turned in either direction beyond this point, the refracted lines approach each other, until the short diagonal or obtuse angles, correspond with the line, when the double refraction ceases entirely, and only a single line appears.

Explanation.—The cause of this difference is, that when the acute angles of the rhomb correspond to the black line, the refracted ray is most widely separated from the common ray, which depends on the thickness of the crystal, but when the position is reversed, the common ray is brought into the exact line of the refracted one, thus forming only a single line.

CATOPTRICS, OR THE REFLECTION OF LIGHT.

25. If a boy throws his ball against the side of a house swiftly, and in a perpendicular direction, it will bound back nearly in the line in which it was thrown, and he will be able to catch it with his hands; but if the ball be thrown obliquely to the right, or left, it will bound away from the side of the house in the same relative direction in which it was thrown.

FIG. 200.

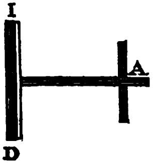


FIG. 201.

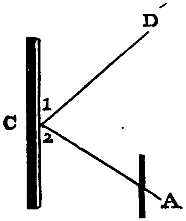
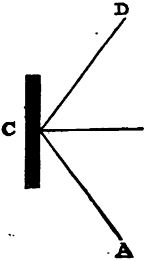


FIG. 202.



Reflection of Light.

The reflection of light, so far as regards the line of approach, and the line of leaving a reflecting surface, is governed by the same law.

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25. Suppose a sunbeam falls upon a plane mirror, at right angles with its surface, in what direction will it be reflected.

Thus, if a sunbeam, *Fig.* 200, passing through a small aperture in the window-shutter, A, be permitted to fall upon the plane mirror, or looking-glass, I D, at right-angles, it will be reflected back at right-angles with the mirror, and therefore will pass back again in exactly the same direction in which it approached.

26. But if the ray strikes the mirror in an oblique direction, it will also be thrown off in an oblique direction, opposite to that from which it came.

Let a ray pass toward a mirror in the line, A C, *Fig.* 201, it will be reflected off in the direction C D, making the angles 1 and 2 exactly equal.

The ray, A C, is called the *incident* ray, and the ray, C D, the *reflected* ray; and it is found, in all cases, that whatever angle the ray of incidence makes with the reflecting surface, or with a perpendicular line drawn from the reflecting surface, exactly the same angle is made by the reflected ray.

27. From these facts, arises the general law in optics, that the *angle of reflection is equal to the angle of incidence.*

The ray, A C, *Fig.* 202, is the ray of incidence, and that from C to D, is the ray of reflection. The angles which A C make with the perpendicular line, and with the plane of the mirror, are exactly equal to those made by C D, with the same perpendicular, and the same plane surface.

MIRRORS.

28. *Mirrors are of three kinds, namely, plane, convex, and concave. They are made of polished metal, or of glass covered on the back with an amalgam of tin and quicksilver.*

Plane Mirror.—The common *looking-glass* is a plane mirror, and consists of a plate of ground glass so highly polished as to permit the rays of light to pass through it with little interruption. On the back of this plate is placed the reflecting surface, which consists of a mixture of tin and mercury. The glass plate, therefore, only answers the purpose of sustaining the metallic surface in its place—of admitting the rays of light to and from it, and of preventing its surface from tarnishing, by excluding the air. Could the metallic surface, however, be retained in its place, and not exposed to the air, without the glass plate, these mirrors would be much more perfect than

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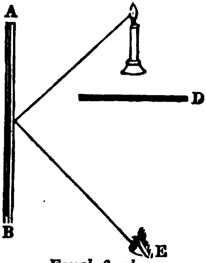
26. Suppose the ray falls obliquely on its surface, in what direction will it then be reflected? What is an incident ray of light? What is a reflected ray of light? 27. What general law in optics results from observations on the incident and reflected rays? 28. How many kinds of mirrors are there? What kind of mirror is the common looking-glass? Of what use is the glass plate in the construction of this mirror?

they are, since in practice, glass can not be made so perfect as to transmit all the rays of light which fall on its surface.

29. When applied to the plane mirror, the angles of incidence and of reflection are equal, as already stated; and it therefore follows, that when the rays of light fall upon it obliquely in one direction, they are thrown off under the same angle in the opposite direction.

FIF. 203



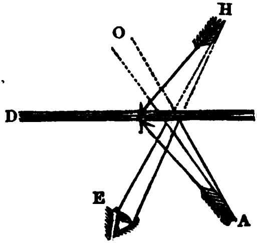
Equal Angles.

This is the reason why the images of objects can be seen when the objects themselves are not visible.

Suppose the mirror A B, *Fig.* 203, to be placed on the side of a room, and a lamp to be set in another room, but so situated as that its light would shine upon the glass. The lamp itself could not be seen by the eye placed at E, because the partition D is between them; but its image would be visible at E, because the angle of the incident ray, coming from the light, and that of the reflected ray which reaches the eye, are equal.

30. *An image from a plane mirror appears to be just as far behind the mirror, as the object is before it, so that when a person approaches this mirror, his image seems to come forward to meet him; and when he withdraws from it, his image appears to be moving backward at the same rate.*

FIG. 204.



Plane Mirror.

If, for instance, one end of a rod, two feet long, be made to touch the surface of such a mirror, this end of the rod, and its image, will seem nearly to touch each other, there being only the thickness of the glass between them; while the other end of the rod, and the other end of its image, will appear to be equally distant from the point of contact.

31. The reason of this is explained on the principle that the angle of incidence and that of reflection are equal.

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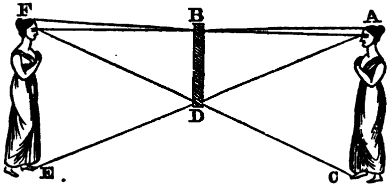
29. Explain Fig. 203, and show how the image of an object can be seen in a plane mirror when the real object is invisible. 30. The image of an object appears just as far behind a plane mirror, as the object is before it. 31. Explain Fig. 204, and show why this is the case.

Suppose the arrow, A, to be the object reflected by the mirror, D C, *Fig.* 204; the incident rays, A, flowing from the end of the arrow, being thrown back by reflection, will meet the eye in the same state of divergence that they would do, if they proceed to the same distance behind the mirror, that the eye is before it, as at O. Therefore, by the same law, the reflected rays, where they meet the eye at E, appear to diverge from the point, H, just as far behind the mirror as A is before it, and consequently the end of the arrow most remote from the glass will appear to be at H, or the point where the approaching rays would meet, were they continued onward behind the glass. The rays flowing from every other part of the arrow follow the same law; and thus every part of the image seems to be at the same distance behind the mirror, that the object really is before it.

32. *In a plane mirror, a person may see his whole image, when the mirror is only half as long as himself, let him stand at any distance from it whatever.*

This is also explained by the law, that the angles of incidence and reflection are equal. If the mirror be elevated so that the ray of light from the eye falls perpendicular upon the mirror, this ray will be thrown back by reflection in the same direction, so that the incident and reflected ray by which the image of the eyes and face are formed, will be nearly parallel, while the ray flowing from his feet will fall on the mirror obliquely, and will be reflected as obliquely in the contrary direction, and so of all the other rays by which the image of the different parts of the person is formed.

FIG. 205.



Mirror half the Length of the Object.

This will be understood by *Fig.* 205, where the ray of light A B, proceeding from the eye, falling perpendicularly on the plane mirror, B D, will be reflected back in the same line; but the ray, C D, coming from the feet, which falls obliquely on the mirror, will be reflected back under the same angle in the line, D A; and since we see objects in the direction of the reflected rays, and the image appears at the

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32. What must be the comparative length of a plane mirror in which a person may see his whole image? Explain, by the lines in Fig. 205, why it is that a lady may see herself in a mirror one half her length.

same distance behind the mirror that the object is before it, (28,) we must continue the line, A D, to the feet, E, and for the same reason, the rays, A B, from the eye, must be prolonged to F, as far behind the mirror as the line E extends, where the whole image will be represented.

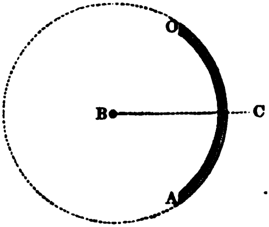
Now, the line, D E, behind the mirror, is just equal to D A before it; and the distance of A C is just twice that of B D; therefore, the whole person is seen in a mirror of half its length, the image being as far behind the reflector as the object is before it.

33. A shorter mirror would not show the whole person, because the rays coming from the feet would fall so obliquely upon it as to be reflected above his head, and thus could not be seen; but, another, placed there, might see the whole image, though the owner could not.

34. Convex Mirror.—*A convex mirror is a part of a sphere, or globe, reflecting from the outside.*

Suppose *Fig.* 206 to be a sphere, then the part from A to O would be a section of the sphere. Any part of a hollow ball of glass, with an amalgam of tin and quicksilver spread on the inside, or any part of a metallic globe, polished on the outside, would form a convex mirror.

FIG. 206.

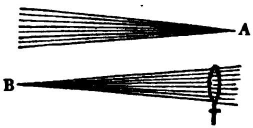


Convex Mirror.

The *axis* of a convex mirror, is a line, as C B, passing through its center.

35. *Divergent and Convergent Rays.*—Rays of light are said to *diverge* when they proceed from the same point, and constantly recede from each other, as from the point, A, *Fig.* 207. Rays of light are said to *converge* when they approach in such a direction as finally to meet at a point, as at B, *Fig.* 207.

FIG. 207.



Rays of Light.

The image formed by a plane mirror, as we have already

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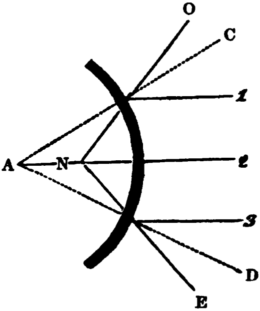
33. Why can not a person see his whole figure in a mirror less than half his length? 34. What is a convex mirror? What is the axis of a convex mirror? 35. What are diverging rays? What are converging rays?

seen, is of the same size as the object, but the image reflected from the convex mirror is always smaller than the object.

The law which governs the passage of light, with respect to the angles of incidence and reflection, to and from the convex mirror, is the same as already stated for the plane mirror.

36. From the surface of a plane mirror, parallel rays are reflected parallel; but, the convex mirror causes parallel rays falling on its surface to *diverge*, by reflection.

FIG. 208.



Divergent Rays.

37. To make this understood, let 1, 2, 3, *Fig.* 208, be parallel rays, falling on the surface of the convex reflector, of which A would be the center, were the reflector a whole sphere. The ray 2, is perpendicular to the surface of the mirror; for, when continued in the same direction, it strikes the axis or center of the circle, A. The two rays, 1 and 3, being parallel to this, all three would fall on a plane mirror in a perpendicular direction, and, consequently, would be reflected in the lines of their incidence. But, the obliquity of the convex surface, it is obvious, will render the direction of the rays 1 and 3 oblique to that surface, for the same reason that 2 is perpendicular to that part of the circle on which it falls. Rays falling on any part of this mirror, in a direction, which, if continued through the circumference, would strike the center, are perpendicular to the side where they fall. Thus, the dotted lines, C A and D A, are perpendicular to the surface, as well as 2.

Now, the reflection of the ray 2, will be back in the line of its incidence, but the rays 1 and 3, falling obliquely, are reflected under the same angles as those at which they fell, and therefore their lines of reflection will be as far without the perpendicular lines C A and D A, as the lines of their incident rays, 1 and 3, are within them, and, consequently, they will diverge in the direction of E and O; and, since we always see the image in the direction of the reflected ray, an object placed at one would appear behind the surface of the mirror, at N, or in the direction of the line, O N.

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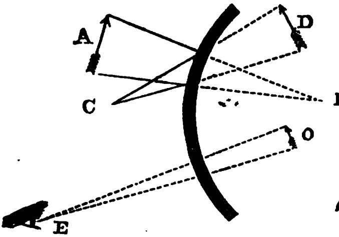
35. What law governs the passage of light from and to the convex mirror? 36. Are parallel rays, falling on a convex mirror, reflected parallel? 37. Explain Fig. 208.

WHY OBJECTS APPEAR LARGE OR SMALL.

38. Objects appear to us large or small in proportion to the angle which the rays of light, proceeding from their extreme parts, form, when they meet at the eye. For, it is plain that the half of any object will appear under a less angle than the whole, and the quarter under a less angle still. Therefore, the smaller an object is the smaller will be the angle under which it will appear at a given distance. *Hence, the image of an object, when reflected from the convex mirror, appears smaller than the object itself.* This will be understood by *Fig.* 209.

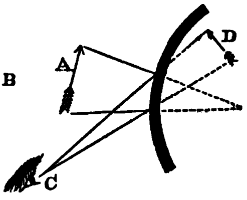
39. Suppose the rays flowing from the extremities of the object, A, to be reflected back to C, under the same degrees of convergence at which they strike the mirror; then, as in the plane mirror, the image, D, would appear of the same size as the object, A; for, if the rays from A were prolonged behind the mirror, they would meet at B; but, forming the same angle, by reflection that they would do if thus prolonged, the object seen from B, and its image from C, would appear of the same dimensions.

FIG. 209.



Object Diminished.

FIG. 210.



Convex Mirror.

But, instead of this, the rays from the arrow, A, being rendered less convergent by reflection, are continued onward, and meet the eye under a more acute angle than at C, the angle under which they actually meet, being represented at E, consequently the image of the object is shortened in proportion to the acuteness of this angle, and the object appears diminished, as represented at O.

---

38. Why does an image reflected from a convex surface appear smaller than the object?
39. Why does the half of an object appear to the eye smaller than the whole?

40. *The image of an object appears less as the object is removed to a greater distance from a convex mirror.*

To explain this, let us suppose that the arrow A, *Fig.* 210, is diminished by reflection from the convex surface, so that its image, appearing at D, with the eye at C, shall seem as much smaller, in proportion to the object, as D is less than A. Now, keeping the eye at the same distance from the mirror, withdraw the object, so that it shall be equally distant with the eye, and the image will gradually diminish, as the arrow is removed.

The reason will be made plain by the next figure; for, as the arrow is moved backward, the angle at C, *Fig.* 211, must be diminished, because the rays, flowing from the extremities of the object, fall a greater distance before they reach the surface of the mirror; and, as the angles of the reflected rays bear a proportion to those of the incident ones, so the angle of vision will become less in proportion, as the object is withdrawn. The effect, therefore, of withdrawing the object is, first, to lessen the distance between the converging rays, flowing from it, at the point where they strike the mirror, and, as a consequence, to diminish the angle under which the reflected rays convey its image to the eye.

41. *Why the Image seems near the Surface.*—In the plane mirror, as already shown, the image appears exactly as far behind the mirror as the object is before it; but, the convex mirror shows the image just under the surface, or, when the object is removed to a distance, a little way behind it. To understand the reason of this difference, it must be remembered that the plane mirror makes the image seem as far behind as the object is before it, because the rays are reflected in the same relative position at which they fall upon its surface. Thus, parallel rays are reflected parallel; divergent rays equally divergent, and convergent rays equally convergent. But, the convex mirror, as also above shown, (33) reflects convergent rays less convergent, and divergent rays more divergent; and, it is from this property of the convex mirror that the image appears near its surface, and not as far behind it as the object is before it, as in the plane mirror.

Let us suppose that A, *Fig.* 212, is a luminous point, from which a pencil of diverging rays falls upon a convex mirror.

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40. How is the image affected when the object is withdrawn from the surface of a convex mirror? Explain Figs. 209 and 210, and show the reason why the images are diminished when the objects are removed from the convex mirror. What is said to be the effect of withdrawing the object from a convex surface, and what the consequence on the angle of reflected rays? 41. Explain the reason why the image appears near the surface of the convex mirror.

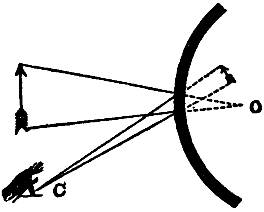

FIG. 211.

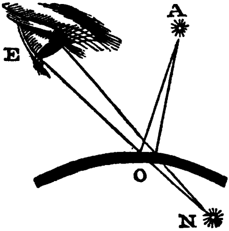

FIG. 212.

These rays, as already demonstrated, will be reflected more divergent, and consequently will meet the eye at E, in a wider state of dispersion than they fell upon the mirror at O. Now, as the image will appear at the point where the diverging rays would converge to a focus in a contrary direction, were they prolonged behind the mirror, so it can not appear as far behind the reflecting surface as the object is before it; for, the more widely the rays meeting at the eye are separated, the shorter will be the distance at which they will come to a point. The image will, therefore, appear at N, instead of appearing at an equal distance behind the mirror that the object, A, is before it.

CONCAVE MIRROR.

42. *The reflection of the concave mirror takes place from its inside, or concave surface, while that of the convex mirror is from the outside, or convex surface.* Thus, the section of a metallic sphere, polished on both sides, is both a *concave* and *convex* mirror, as one or the other side is employed for reflection.

The effects and phenomena of this mirror will therefore be, in many respects, directly the contrary from those already detailed in reference the convex mirror.

From the *plane* mirror, the relation of the incident rays is not changed by reflection; from the *convex* mirror they are dispersed; *but, the concave mirror renders the rays reflected from it more convergent, and tends to concentrate them into a focus.*

The surface of the concave mirror, like, that of the convex, may be considered as a great number of minute plane mirrors, inclined to, instead of from, each other at certain angles, in proportion to its concavity.

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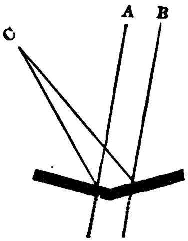
42. What is the shape of the concave mirror, and in what respect does it differ from the convex mirror? How may convex and concave mirrors be united in the same instrument? What is the difference of effect between the concave, convex, and plane mirrors, on the reflected rays?

The laws of incidence and reflection are the same, when applied to the concave mirror, as those already explained in reference to the other mirrors.

43. *Plane Mirrors Inclined.*—In reference to the concave mirror, let us, in the first place, examine the effect of two plane mirrors inclined to each other, as in *Fig.* 213, on parallel rays of light. The incident rays, A and B, being parallel before they reach the reflectors, are thrown off at unequal angles in respect to each other, for B falls on the mirror more obliquely than A, and, consequently, is thrown off more obliquely in a contrary direction, therefore, the angles of reflection being equal to those of incidence, the two rays meet at C.

FIG. 213.



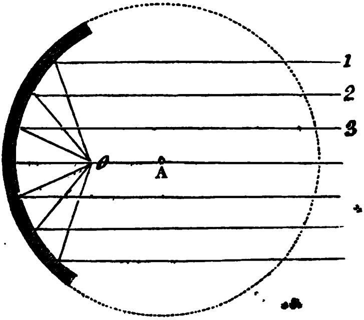
Thus, we see that the effect of two plane mirrors, inclined to each other, is to make parallel rays converge and meet in a focus.

The effect of this mirror, as we have seen, being to render parallel rays convergent, the same principle will render diverging rays parallel, and converging rays still more convergent.

44. *Focus of a Concave Mirror.*—The *focus* of a concave mirror is the point where the rays are brought together by reflection. The *center of concavity* in a concave mirror, is the center of the sphere, of which the mirror is a part. In all concave mirrors, the focus of parallel rays, or rays falling directly from the sun, is at the distance of half the semi-diameter of the sphere or globe, of which the reflector is a part.

Thus, the parallel rays 1, 2, 3, &c., *Fig.* 214, all meet at the point, O, which is half the distance between the center, A, of the whole sphere and the surface of the reflector, and, therefore,

FIG. 214.



Focus of a Concave Mirror.

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43. In what respect may the concave mirror be considered as a number of plane mirrors? 44. What is the focus of a concave mirror? At what distance from its surface is the focus of parallel rays in this mirror?

one quarter the diameter of the whole sphere, of which the mirror is a part.

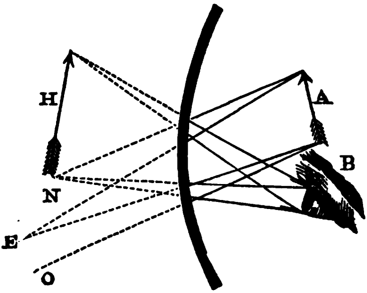
45. *Principal Focus.*—in concave mirrors, of all dimensions, the reflected rays follow the same law; that is, parallel rays meet and cross each other at the distance of one-fourth the diameter of the sphere of which they are sections. This point is called the *principal* focus of the reflector.

But if the incident rays are divergent, the focus will be removed to a greater distance from the surface of the mirror, than when they are parallel, in proportion to their divergence.

46. OBJECTS WITHIN THE FOCUS.—*The concave mirror, when the object is nearer to it than the principal focus, presents the image larger than the object, erect, and behind the mirror.*

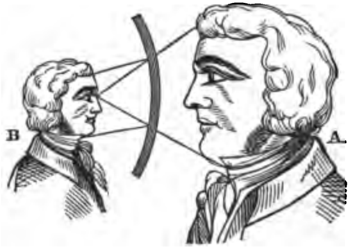
To explain this, let us suppose the object, A, *Fig.* 215, to be placed before the mirror, and nearer to it than the principal focus. Then the rays proceeding from the extremities of the object without any interruption, would continue to diverge in the lines, O and N, as seen behind the mirror; but, by reflection they are made to diverge less than before, and consequently to make the angle under which they meet more obtuse at the eye, B, than it would be if they continued onward to E, where they would have met without reflection. The result, therefore, is to render the image, H, upon the eye, as much larger than the object, A, as the angle at the eye is more obtuse than the angle at C.

FIG. 215.



Object Within the Focus.

FIG. 216.



Magnified Human Face.

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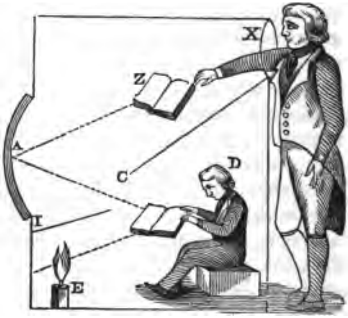
45. What is the principle focus of a concave mirror? 46. When will the image from a concave mirror be larger than the object, erect, and behind the mirror? Explain Fig. 215, and show why the image is larger than the object.

47. *Magnified Human Face.*—A more striking illustration of this principle is seen at *Fig.* 216. When the concave mirror is large, say six inches in diameter, and eight or ten inches focal distance, it exhibits the human face of enormous bulk, the spectator being frightened at the size and coarseness of his own features. Thus if the face be presented within the principal focus of the mirror, as at B, the magnified image will be seen as far behind the mirror as the face is before it, as at A, and will appear two or three times the size of the face, according to the power of the reflector; the reason of which has already been explained and illustrated by *Fig.* 216.

48. *Curious Deceptions by Concave Mirrors.*—From the property of the concave mirror to form an inverted image of the object suspended in the air, many curious and surprising deceptions may be produced. Thus, when the mirror, the object, and the light, are placed so that they can not be seen, (which may be done by placing a screen before the light, and permitting the reflected rays to pass through a small aperture in another screen,) the person mistakes the image of the object for its reality, and not understanding the deception, thinks he sees persons walking with heads downward, and cups of water turned bottom upward, without spilling a drop. Again he sees clusters of delicious fruit, and when invited to help himself, on reaching out his hand for that purpose, he finds that the object either suddenly vanishes from his sight, owing to his having moved his eye out of the proper range, or that it is intangible.

49. One method of effecting such deceptions, is shown by *Fig.* 217, where A is a large concave mirror, six or eight inches in diameter, placed on the back part of a dark box; the performer, D, is concealed from the spectators by the partition, C; the strong light, E, is also concealed by the partition, I, but is thrown upon the actor, or any thing he holds in his hand. If he holds a book, as shown by

FIG. 217.



Deceptions by Concave Mirrors.

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47. What is the effect when the face is seen within the principal focus of this mirror? 48. What property has the concave mirror, by which singular deceptions may be produced? What are these deceptions? 49. Explain Fig. 217, and show how the deception is produced.

the figure, the light reflected from A, will pass between the partitions, C and I, to the mirror, and will reflect the image of the book to Z, where it will appear so distinct and tangible, that a person looking through the opening at X, will have no doubt that it is a real book, and will be much astonished to find, when he puts out his hand to take it, that it has no substance, and that his hand will pass through it, as though it was nothing but a shadow, which he can not at first be made to believe is the case.

50. *Heat Produced by a Concave Mirror.*—The concave mirror having the property of converging the rays of light, is equally efficient in concentrating the rays of heat, either separately or with the light. When, therefore, such a mirror is presented to the rays of the sun, it brings them to a focus, so as to produce degrees of heat in proportion to the extent and perfection of its reflecting surface. A metallic mirror of this kind, of only four or six inches in diameter, will fuse metals, set wood on fire, &c.

51. *Experiment with a Hot Ball.*—As the parallel rays of heat or light are brought to a focus at the distance of one quarter of the diameter of the sphere, of which the reflector is a section, so if a luminous or heated body be placed at this point, the rays from such body passing to the mirror, will be reflected from all parts of its surface, in parallel lines; and the rays so reflected by the same law, will be brought to a focus by another mirror standing opposite to this.

52. Suppose a red-hot ball to be placed in the principal focus of the mirror, A, *Fig.* 218, the rays of heat and light proceeding from it will be reflected in the parallel lines, 1, 2, 3, &c. The reason of this is the same as that which causes parallel rays, when falling on the mirror, to be converged to a focus. The angles of incidence being equal to those of reflection, it makes no difference in this respect, whether the rays pass to or from the focus. In one case, parallel incident rays from the sun, are concentrated by reflection; and in the other, incident diverging rays, from the heated ball, are made parallel by reflection.

The rays, therefore, flowing from the hot ball to the mirror, A, are thrown into parallel lines by reflection, and these re-

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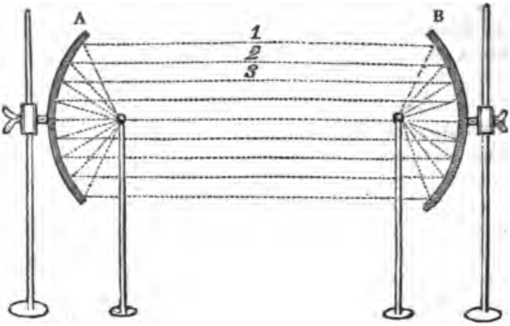
50. Will the concave mirror concentrate the rays of heat, as well as those of light? 51. Suppose a luminous body be placed in the focus of a concave mirror, in what direction will its rays be reflected? 52. Explain Fig. 218, and show why the rays from the focus of A, are concentrated in the focus, B. What curious experiments may be made by two concave mirrors placed opposite to each other by a hot ball? How may it be shown that heat and light are distinct principles?

FIG. 218.



Reflection of Heat.

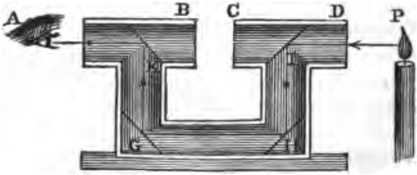
flected rays, in respect to the mirror, B, become the rays of incidence, which are again brought to a focus by reflection.

Thus the heat of the ball, by being placed in the focus of one mirror, is brought to a focus by the reflection of the other mirror.

To show that heat and light are separate principles, place a piece of phosphorus in the focus of B, and when the ball is so cool as not to be luminous, remove the screen, and the phosphorus will instantly inflame.

53. *Deception by Several Mirrors.*—The wonderful feat of reading through a brick, sometimes exhibited in the streets, at a penny a head, is explained by *Fig.* 219.

FIG. 219.



Reading through a Brick.

The apparatus consists of five short tubes jointed at right-angles, and containing four mirrors placed at the angle of 45° to the incident rays of light, flowing, first, from the object to be

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53. Explain by Fig. 219, how a candle can apparently be seen through a brick

seen, and then from one mirror to the other. Thus, the rays from the object, P, pass to the mirror, L, through the tube, D C, and from L, are reflected to H, and from H, horizontally, to G, and from G, vertically to K, and lastly, from K, horizontally to the eye.

Now the angle of reflection, being equal to that of incidence, each mirror has the effect to change the direction of the rays of light equal to that of a quarter of a circle, and the four mirrors, therefore, produce a change equal to that of an entire circle.

REFRACTION BY LENSES.

54. *A Lens is a transparent body, generally made of glass, and so shaped that the rays of light in passing through it are either collected together or dispersed.* Lens is a Latin word, which comes from *lentile*, a small flat bean.

It has already been shown, that when the rays of light pass from a rarer to a denser medium, they are refracted, or bent out of their former course, except when they happen to fall perpendicularly on the surface of the medium. (19.)

The point where no refraction is produced on perpendicular rays, is called the *axis* of the lens, which is a right line passing through its center, and perpendicular to both its surfaces.

In every beam of light the middle ray is called its *axis*.

Rays of light are said to fall *directly* upon a lens, when their axis coincides with the axis of the lens; otherwise they are said to fall *obliquely*.

The point at which the rays of the sun are collected, by passing through a lens, is called the *principal focus* of that lens.

55. Lenses are of various kinds, and have received certain names, depending on their shapes. The different kinds are shown at *Fig.* 220.

A *prism*, seen at A, has two plane surfaces, A R, and A S, inclined to each other.

A *plane glass*, shown at B, has two plane surfaces, parallel to each other.

A *spherical lens*, C, is a ball of glass, and has every part of its surface at an equal distance from the center.

A *double-convex lens*, D, is bounded by two *convex* surfaces, opposite to each other.

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54. What is a lens? What is the axis of a lens? In what part of a lens is no refraction produced? Where is the axis of a beam of light? When are rays of light said to fall directly upon a lens? How many kinds of lenses are mentioned? 55. What are the names and shapes of each.

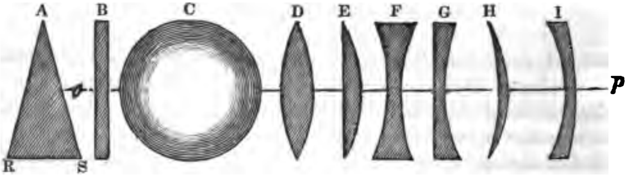
A *plano-convex lens*, E, is bounded by a convex surface on one side and a plane one on the other.

A *double-concave lens*, F, is bounded by two concave spherical surfaces, opposite to each other.

A *plano-concave lens*, G, is bounded by a plane surface on one side, and a concave one on the other.

A *meniscus*, H, is bounded by one concave, and one convex spherical surface, which two surfaces meet at the edge of the lens.

FIG. 220.



Lenses of Various Forms.

A *concavo-convex lens*, I, is bounded by a concave, and convex surface, but which diverge from each other, if continued.

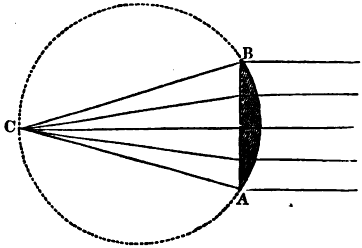
The effects of the prism on the rays of light will be shown in another place. The refraction of the *plane* glass bends the parallel rays of light equally toward the perpendicular, as already shown. The *sphere* is not often employed as a lens, since it is inconvenient in use.

CONVEX LENS.

56. *The effect of the convex lens, by increasing the visual angle, is to magnify all objects seen through it.*

Focal Distance.—The focal distances of convex lenses, depend on their degrees of convexity. The focal distance of a *single*, or plano-convex lens, is the diameter of a sphere, of which it is a section.

FIG. 221.



Plano-convex Lens.

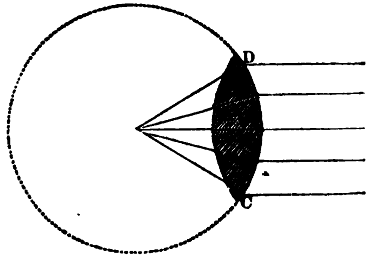
What is the effect of the convex lens? On what do the focal distances of convex lenses depend?

If the whole circle, *Fig.* 221, be considered the circumference of a sphere, of which the plano-convex lens, B A, is a section, then the focus of parallel rays, or the principal focus, will be at the opposite side of the sphere, or at C.

57. The focal distance of a *double*-convex lens, is the radius, or half the diameter of the sphere, of which it is a part. Hence the plano-convex lens, being one half of the double-convex lens, the latter has twice the refractive power of the former; for the rays suffer the same degree of refraction in passing *out* of the one convex surface, that they do in passing *into* the other.

58. *Double-Convex Lens.*—The shape of the double-convex lens, D C, *Fig.* 222, is that of two plano-convex lenses, placed with their plane surfaces in contact, and consequently the focal distance of this lens is nearly the center of the sphere of which one of its surfaces is a part. If parallel rays fall on a convex lens, it is evident that the ray only, which penetrates the axis and passes toward the center of the sphere, will proceed without refraction, as shown in the above figures. All the others will be refracted so as to meet the perpendicular ray at a greater or less distance, depending on the convexity of the lens.

FIG. 222.



Double-Convex Lens.

59. DIVERGING RAYS ON A CONVEX LENS.—*If diverging rays fall on the surface of this lens, they will, by refraction, be rendered less divergent, parallel, or convergent, according to the degrees of their divergence, and the convexity of the surface of the lens.*

Thus, the diverging rays, 1, 2, &c., *Fig.* 223, are refracted by the lens, A O, in a degree just sufficient to render them parallel, and therefore, would pass off in right lines, indefinitely, or without ever forming a focus.

It is obvious by the same law, that were the rays less divergent, or were the surface of the lens more convex, the rays in *Fig.* 223, would become convergent, instead of parallel,

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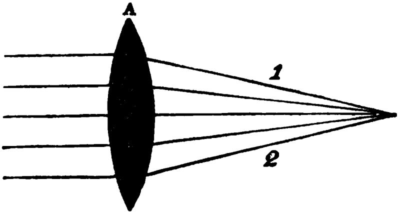
57. What is the focal distance of any plano-convex lens? What is the focal distance of the double-convex lens? 58. What is the shape of the double-convex lens? 59. How are divergent rays affected by passing through a convex lens? What is its effect on parallel rays? What is its effect on converging rays?

FIG. 223.



Diverging Rays.

because the same refractive power which would render divergent rays parallel, would make parallel rays convergent, and converging rays still more convergent..

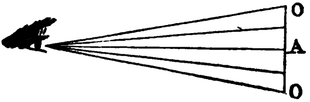
The eyeglasses of spectacles for old people are double-convex lenses, more or less spherical, according to the age of the person, or the magnifying power required.

60. Burning Glass.—The common burning glasses, which are used for lighting cigars, and sometimes for kindling fires, are also convex lenses. Their effect is to concentrate to a focus, or point, the heat of the sun which falls on their whole surface; and hence the intensity of their effects is in proportion to the extent of their surfaces, and their focal lengths.

61. Visual Angle.—It has been explained, that the reason why the convex mirror diminishes the images of objects is, that the rays which come to the eye from the extreme parts of the object are rendered less convergent by reflection, from the convex surfaçe, and that in consequence, the angle of vision is made more acute. (41.)

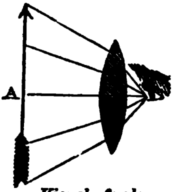
62. Now, the refractive power of the convex lens has exactly e contrary effect, since by converging the rays flowing from the extremities of an object, the visual angle is rendered more obtuse, and therefore all objects seen through it appear magnified.

FIG. 224.



Visual Angle.

FIG. 225



Visual Angle.

What kind of lenses are spectacle glasses for old people? 60. What kind of a lens is a burning glass? 61. What is the visual angle? 62. What is the effect of the convex lens on the visual angle?

63. Suppose the object, A, *Fig.* 224, appears to the naked eye of the length represented in the drawing. Now, as the rays coming from each end of the object, form by their convergence at the eye, the *visual angle*, or the angle under which the object is seen, and we call objects large or small in proportion as this angle is obtuse or acute, if, therefore, the object, A, be withdrawn further from the eye, it is apparent that the rays O O, proceeding from its extremities, will enter the eye under a more acute angle, and, therefore, that the object will appear diminished in proportion. This is the reason why things at a distance appear smaller than when near us. When near, the visual angle is increased, and when at a distance it is diminished.

The effect of the convex lens is to increase the visual angle, by bending the rays of light coming from the object, so as to make them meet at the eye more obtusely; and hence it has the same effect, in respect to the visual angle, as bringing the object nearer the eye. This is shown by *Fig.* 225, where it is obvious, that did the rays flowing from the extremities of the arrow meet the eye without refraction, the visual angle would be less, and therefore the object would appear shorter. Another effect of the convex lens, is to enable us to see objects nearer the eye than without it, as will be explained under the article *Vision.*

Now, as the rays of light flow from all parts of a visible object of whatever shape, so the breadth, as well as the length, is increased by the convex lens, and thus the whole object appears magnified.

64. CONCAVE LENS.—*The effect of the concave lens is directly opposite to that of the convex.* In other terms, by a concave lens, parallel rays are rendered diverging, converging rays have their convergence diminished, and diverging rays have their divergence increased, according to the concavity of the lens.

These glasses, therefore, exhibit things smaller than they really are, for by diminishing the convergence of the rays coming from the extreme points of an object, the visual angle is rendered more acute, and hence the object appears diminished by this lens, for the opposite reason, that it is increased by the convex lens. This will be made plain by the two following diagrams.

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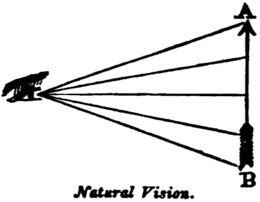
63. Why does the same object, when at a distance, appear smaller than when near? Why does an object appear larger through the convex lens than otherwise? 64. What is the effect of the concave lens? What effect does this lens have upon parallel, diverging, and converging rays? Why do objects appear smaller through this glass than they do to the naked eye? Explain Figs. 226 and 227, and show the reason why the same object appears smaller through 227. What defect in the eye requires concave lenses?

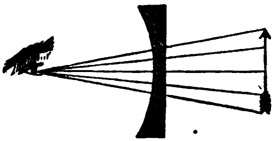
Suppose the object, A B, *Fig.* 226, to be placed at such a distance from the eye, as to give the rays flowing from it, the degrees of convergence represented in the figure, and suppose that the rays enter the eye under such an angle as to make the object appear two feet in length.

FIG. 226.



Natural Vision.

FIG. 227.



Plano-Concave Lens.

Now, the length of the same object, seen through the concave lens, *Fig.* 227, will appear diminished, because the rays coming from it are bent outward, or made less convergent by refraction, as seen in the figure, and consequently the visual angle is more acute than when the same object is seen by the naked eye. Its length, therefore, will appear less in proportion as the rays are rendered less convergent.

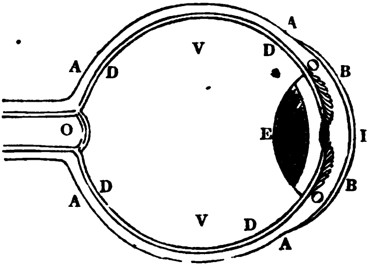
The spectacle glasses of short-sighted people are concave lenses, by which the images of objects are formed further back in the eye than otherwise, as will be explained under the next article.

VISION.

65. *In the application of the principles of optics to the explanation of natural phenomena, it is necessary to give a description of the most perfect of all optical instruments, the eye.*

Human Eye.—Fig. 228 is a vertical section of the human eye. Its form is nearly globular, with a slight projection

FIG. 228.



Human Eye.

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65. What is the most perfect of all optical instruments? What is the form of the human eye? How many coats or membranes has the eye? What are they called?

or elongation in front. It consists of four coats, or membranes; namely, the *sclerotic*, the *cornea*, the *choroid*, and the *retina.* It has two fluids confined within these membranes, called the *aqueous*, and the *vitreous* humors, and one lens, called the *crystaline.* The sclerotic coat is the outer and strongest membrane, and its anterior part is well known as the *white* of the eye. This coat is marked in the figure, A A A A. It is joined to the cornea, B B, which is the transparent membrane in front of the eye, through which we see. The choroid coat is a thin, delicate membrane, which lines the sclerotic coat on the inside. On the inside of this lies the *retina*, D D D D, which is the innermost coat of all, and is an expansion, or continuation of the optic nerve, O. This expansion of the optic nerve is the immediate seat of vision. The iris, I, is seen through the cornea, and is a thin membrane, or curtain, of different colors in different persons, and therefore gives color to the eyes. In black-eyed persons it is black, in blue-eyed persons it is blue, &c. Through the iris, is a circular opening, called the *pupil*, which expands or enlarges when the light is faint, and contracts when it is too strong. The space between the iris and the cornea is called the *anterior chamber* of the eye, and is filled with the *aqueous* humor, so called from its resemblance to water. Behind the pupil and iris is situated the crystaline lens, E, which is a firm and perfectly transparent body, through which the rays of light pass from the pupil to the retina. Behind the lens is situated the *posterior chamber* of the eye, which is filled with the *vitreous humor*, V V. This humor occupies much the largest portion of the whole eye, and on it depends the shape and permanence of the organ.

From the above description of the eye it will be easy to trace the progress of the rays of light through its several parts, and to explain in what manner vision is performed.

In doing this, we must keep in mind that the rays of light proceed from every part and point of a visible object, as heretofore stated, and that it is necessary only for a few of the rays, when compared with the whole number, to enter the eye, in order to make the object visible.

OPTICAL AXIS.

67. In *Fig.* 229, presenting a front view of the eyes, W W shows the *white*, I the *iris*, and P the *pupil.*

A straight line, passing through the center of the cornea,

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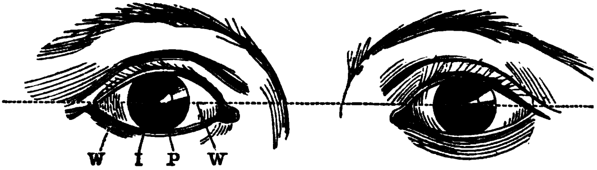
65. How many fluids has the eye, and what are they called? What is the lens of the eye called? What coat forms the white of the eye? Describe where the several coats and humors are situated. What is the iris? What is the retina? Where is the sense of vision? What is the design of Fig. 229? What is said concerning the small number of the rays which enter the eye from a visible object?

FIG. 229.

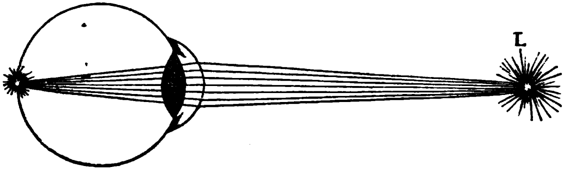


Human Eyes.

coinciding with the axis of the crystaline lens, and dividing equally the center of the eye-ball, is called the optical axis, as shown in the cut.

66. *Refraction by the Eye.*—From the luminous body, L, *Fig.* 230, the pencils of rays flow in all directions, but it is only by those which enter the pupil, that we gain any knowledge of its existence; and even these would convey to the mind no distinct idea of the object, unless they were refracted by the humors of the eye, for did these rays proceed in their

FIG. 230.



Refraction by the Eye.

natural state of divergence to the retina, the image there formed would be too extensive, and consequently too feeble to give a distinct sensation of the object.

It is, therefore, by the refracting power of the aqueous humor, and of the crystaline lens, that the pencils of rays are so concentrated as to form a perfect picture of the object on the retina.

Inverted Image on the Retina.—We have already seen that when the rays of light are made to cross each other by reflection from the concave mirror, the image of the object is inverted; the same happens when the rays are made to cross each other by refraction through a convex lens. This, indeed, must be a necessary consequence of the intersection of the rays;

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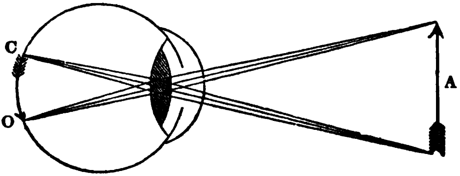
66. Explain the design of Fig. 230. Why would not the rays of light give a distinct idea of the object, without refraction by the humors of the eye? 67. Explain how it is hat the images of objects are inverted on the retina.

for as light proceeds in straight lines, those rays which come from the lower part of an object, on crossing those which come from its upper part, will represent this part of the picture on the upper half of the retina, and, for the same reason, the upper part of the object will be painted on the lower part of the retina.

Now, all objects are represented on the retina in an inverted position; that is, what we call the upper end of a vertical object, is the lower end of its picture on the retina, and so the contrary.

68. *Eye of an Ox.*—This is readily proved by taking the eye of an ox, and cutting away the sclerotic coat, so as to make it transparent on the back part, next the vitreous humor. If now a piece of white paper be placed on this part of the eye, the images of objects will appear figured on the paper in an inverted position. The same effect will be produced on looking at things through an eye thus prepared; they will appear inverted.

FIG. 231.



Inversion of Objects.

The actual position of the vertical object, A, *Fig.* 231, as painted on the retina, is therefore such as is represented by the figure. The rays from its upper extremity, coming in divergent lines, are converged by the crystaline lens, and fall on the retina at O; while those from its lower extremity, by the same law, fall on the retina at C, the rays crossing each other as they pass the humors of the eye.

69. In order that vision may be perfect, it is necessary that the images of objects should be formed precisely on the retina, and consequently, if the refractive power of the eye be too small, or too great, the image will not fall exactly on the seat of vision, but will be formed either before, or tend to form behind it. In

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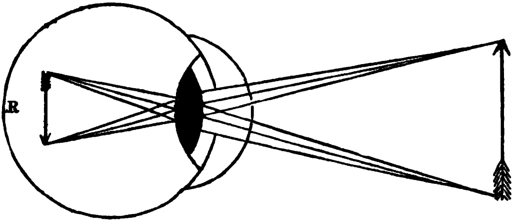
68. What experiment proves that the images of objects are inverted on the retina? Explain Fig 231. 69. Suppose the refractive power of the eye is too great, or too little, why will vision be imperfect?

both cases, perhaps, an outline of the object may be visible, but it will be confused and indistinct.

70. *Cornea too Prominent.*—If the cornea is too convex, or prominent, the image will be formed before it reaches the retina, for the same reason, that of two lenses, that which is most convex will have the least focal distance. Such is the defect in the eyes of persons who are short-sighted, and hence the necessity of their bringing objects as near the eye as possible, so as to make the rays converge at the greatest distance behind the crystaline lens.

The effect of uncommon convexity in the cornea on the rays of light, is shown at *Fig.* 232, where it will be observed that the image, instead of being formed on the retina R, is suspended in the vitreous humor, in consequence of there being too great a refractive power in the eye. It is hardly necessary to say, that in this case, vision must be very imperfectly performed.

FIG. 232.



Cornea too Convex.

This defect of sight is remedied by spectacles, the glasses of which are concave lenses. Such glasses, by rendering the rays of light less convergent, before they reach the eye, counteract the too great convergent power of the cornea and lens, and thus throw the image on the retina.

71. *Cornea too Flat.*—If, on the contrary, the humors of the eye, in consequence of age, or any other cause, have become less in quantity than ordinary, the eye ball will not be sufficiently distended, and the cornea will become too flat, or not sufficiently convex, to make the rays of light meet at the proper place, and the image will therefore tend to be formed beyond the retina, instead of before it, as in the other case. Hence,

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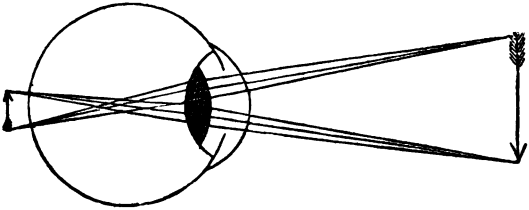
70. If the cornea is too convex, where will the image be formed? How is the sight improved, when the cornea is too convex? How do such lenses act to improve the sight? 71. Where do the rays tend to meet when the cornea is not sufficiently convex? How is vision assisted when the eye wants convexity?

aged people, who labor under this defect of vision, can not see distinctly at ordinary distances, but are obliged to remove the object as far from the eye as possible, so as to make its refractive power bring the image within the seat of vision.

FIG. 233.



Cornea too Flat.

The defect arising from this cause is represented by *Fig.* 233, where it will be observed that the image is formed behind the retina, showing that the convexity of the cornea is not sufficient to bring the image within the seat of distinct vision. This imperfection of sight is common to aged persons, and is corrected in a greater or less degree by double-convex lenses, such as the common spectacle-glasses. Such glasses, by causing the rays of light to converge, before they meet the eye, assist the refractive power of the crystaline lens, and thus bring the focus, or image, within the sphere of vision.

72. *Why we see Objects Erect.*—It has been considered difficult to account for the reason why we see objects erect, when they are painted on the retina inverted, and many learned theories have been written to explain this fact. But it is most probable that this is owing to habit, and that the image at the bottom of the eye, has no relation to the terms above and below, but to the position of our bodies, and other things which surround us. The term *perpendicular*, and the idea which it conveys to the mind, is merely relative; but when applied to an object supported by the earth, and extending toward the skies, we call the body *erect*, because it coincides with the position of our own bodies, and we see it erect for the same reason. Had we been taught to read by turning our books upside down, what we now call the upper part of the book would have been its under part, and that reading would have been as easy in that position as in any other, is plain from the fact that printers

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71. How do convex lenses help the sight of aged persons? 72. Why do we see things erect, when the images are inverted on the retina?

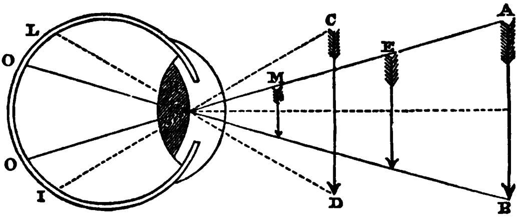
read their type, when set up, as readily as they do its impressions on paper.

ANGLE OF VISION.

73. This subject, partly explained, needs further illustration. *The angle under which the rays of light, coming from the extremities of an object, cross each other at the eye, bears a proportion directly to the length, and inversely to the distance of the object.*

Suppose the object, A B, *Fig.* 234, to be four feet long, and to be placed ten feet from the eye, then the rays flowing from its extremities, would intersect each other at the eye, under a given angle, which will always be the same when the object is at the same distance. If the object be gradually moved toward the eye, to the place, C D, then the angle will be gradually increased in quantity, and the object will appear larger, since its image on the retina will be increased in length in the proportion as the lines I L, are wider apart than O O. On the contrary, were A B removed to a greater distance from the first position, it is obvious that the angle would be diminished in proportion.

FIG. 234.



Angle of Vision.

The lines thus proceeding from the extremities of an object, and representing the rays of light, form an angle at the eye, which is called the *visual angle*, or the angle under which things are seen. The lines, A R B, therefore, form one visual angle, and the lines, C R D, another visual angle.

We see from this investigation, that the apparent magnitude of objects depending on the angles of vision, will vary according

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73. What is the visual angle? How may the visual angle of the same object be increased or diminished? When do objects of different magnitudes form the same visual angle? Explain Fig. 234.

to their distances from the eye, and that these magnitudes diminish in a proportion inversely as their distances increase.

74. How we Judge of Magnitudes.—In the apparent magnitude of objects seen through a lens, or when their images reach the eye by reflection from a mirror, our senses are chiefly, if not entirely, guided by the angle of vision. In forming our judgment of the sizes of distant objects, whose magnitudes were before unknown, we are also guided more or less by the visual angle, though in this case we do not depend entirely on the sense of vision. Thus, if we see two balloons floating in the air, one of which is larger than the other, we judge of their comparative magnitudes by the difference in their visual angles, and of their real magnitudes by the same angles, and the distance we suppose them to be from us.

75. But when the object is near us, and seen with the naked eye, we then judge of the magnitude by our experience, and not entirely by the visual angle. Thus the three arrows, A E M, *Fig.* 234, all of them make the same angle on the eye, and yet we know, by further examination, that they are all of different lengths. And so the two arrows, A B, and C D, though seen under different visual angles, will appear of the same size, because experience has taught us that this difference depends only on the comparative distance of the two objects,

76. As the visual angle diminishes inversely in proportion as the distance of the object increases, so when the distance is so great as to make the angle too minute to be perceptible to the eye, then the object becomes invisible. Thus, when we watch an eagle flying from us, the angle of vision is gradually diminished, until the rays proceeding from the bird form an image on the retina too small to excite sensation, and then we say the eagle has flown out of sight.

77. Size of the Image on the Retina.—The actual size of an image on the retina, capable of exciting sensation, and consequently of producing vision, may be too small for us to appreciate by any of our other senses; for when we consider how much smaller the image must be than the object, and that a human hair can be distinguished by the naked eye at the distance of twenty or thirty feet, we must suppose that the retina is endowed with the most delicate sensibility, to be excited by a cause so minute. It has been estimated that the image of a

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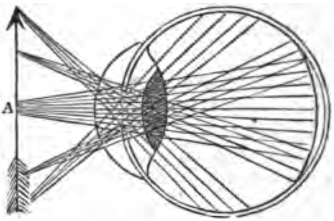
74. How do we judge of the magnitudes of distant objects? Under what circumstances is our sense of vision guided entirely by the visual angle? 75. How do we judge of the comparative size of objects near us? 76. When does a retreating object become invisible to the eye? How does a convex lens act to make us see objects which are invisible without it? 77. What is said of the actual size of an image on the retina?

man, on the retina, seen at the distance of a mile, is not more than the five thousandth part of an inch in length.

78. INDISTINCT VISION.—On the contrary, if the object be brought too near the eye, its image becomes confused and indistinct, because the rays flowing from it, fall on the crystaline lens in a state too divergent to be refracted to a focus on the retina.

This will be apparent by *Fig.* 235, where we suppose that the object, A, is brought within an inch or two of the eye, and that the rays proceeding from it enter the pupil so obliquely as not to be refracted by the lens, so as to form a distinct image.

FIG. 235.



Indistinct Vision.

Could we see objects distinctly at the shortest distance, we should be able to examine things that are now invisible, since the visual angle would then be increased, and consequently the image on the retina enlarged, in proportion as objects were brought near the eye.

79. *Intercepting the Rays.*—This is proved by intercepting the most divergent rays; in which case an object may be brought near the eye, and will then appear greatly magnified. Make a small orifice, as a pin-hole, through a piece of dark-colored paper, and then look through the orifice at small objects, such as the letters of a printed book. The letters will appear much magnified. The rays, in this case, are refracted to a focus, on the retina, because the small orifice prevents those which are most divergent from entering the eye, so that notwithstanding the nearness of the object, the rays which form the image are nearly parallel.

OPTICAL INSTRUMENTS.

80, SINGLE MICROSCOPE.—The principle of the single microscope, or convex lens, will be readily understood, if the pupil will remember what has been said on the refraction of lenses, in connection with the facts just stated. For, the reason why ob-

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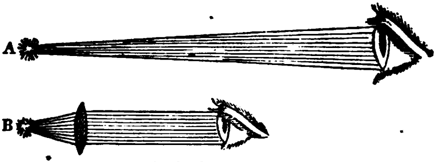
78. Why are objects indistinct when brought too near the eye? Suppose objects could be seen distinctly within an inch or two of the eye, how would their dimensions be affected? 79. How is it proved that objects placed near the eye are magnified? How does a small orifice enable us to see an object distinctly near the eye? 80. Why does a convex lens make an object distinct when near the eye?

jects appear magnified through a convex lens, is not only because the visual angle is increased, but because when brought near the eye, the diverging rays from the object are rendered parallel by the lens, and are thus thrown into a condition to be brought to a focus in the proper place by the humors of the eye.

Let A, *Fig.* 236, be the distance at which an object can be seen distinctly, and B, the distance at which the same object is seen through the lens, and suppose the distance of A from the eye, be twice that of B. Then, because the object is at half the distance that it was before, it will appear twice as large; and had it been seen one-third, one-fourth, or one-tenth its former distance, it would have been magnified three, four, or ten times, and consequently its surface would be increased 9, 16, or 100 times.

FIG. 236.



Single Microscope.

The most powerful single microscopes are made of minute globules of glass, which are formed by melting the ends of a few threads of spun glass in a flame of alcohol. Small globules of water placed in an orifice through a piece of tin, or other thin substance, will also make very powerful microscopes. In these minute lenses, the focal distance is only a tenth or twelfth part of an inch from the lens, and therefore the eye, as well as the object to be magnified, must be brought very near the instrument.

81. Compound Microscope.—This consists of two convex lenses, by one of which the image is formed within the tube of the instrument, and by the other this image is magnified as seen by the eye; so that by this instrument the object itself is not seen, as with the single microscope, but we see only its magnified image.

The small lens placed near the object, and by which its image

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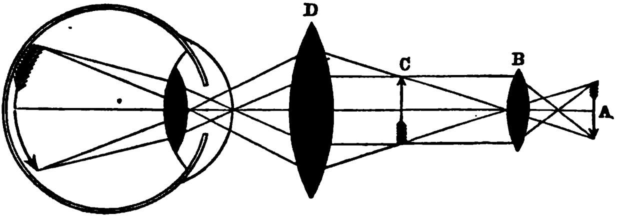
80. Explain Fig. 236. How are the most powerful single microscopes made? **81.** How many lenses form the compound microscope? Which is the object, and which the eye-glass? Is the object seen with this instrument, or only its image? Explain Fig. 237 and show where the image is formed in this tube.

is formed within the tube, is called the *object glass*, while the larger one, through which the image is seen, is called the *eye-glass*.

This arrangement is represented at *Fig.* 237. The object, A, is placed a little beyond the focus of the object glass, B, by which an inverted and enlarged image of it is formed within the instrument at C. This image is seen through the eye-glass, D, by which it is again magnified, and it is at last figured on the retina in its original position.

FIG. 237.



Compound Microscope.

These glasses are set in a case of brass, the object glass being made to take out so that others of different magnifying powers may be used as occasion requires.

82. *Compound Microscope Complete.*—The *principle* of this instrument is only intended to be shown by *Fig.* 237, the instrument complete, ready for use, being represented by *Fig.* 238. Its several parts are as follows: A, eye-glass; B, compound body, or tube; C, objective or optical glass; D, stage on which things are placed for examination; E, mirror to reflect light on the object; F, the stand, made heavy by iron or brass feet; G, thumb-screw and ratchet, to adjust the object to the focus; H, another screw for the same purpose, only more minute; I, an object for examination.

83. Solar Microscope.—This consists of two lenses, one of which is called the *condenser*, because it is employed to concentrate the rays of the sun, in order to illuminate more strongly the object to be magnified. The other is a double convex lens, of considerable magnifying power, by which the image is formed. In addition to these lenses, there is a plain mirror, or piece of common looking-glass, which can be moved in any

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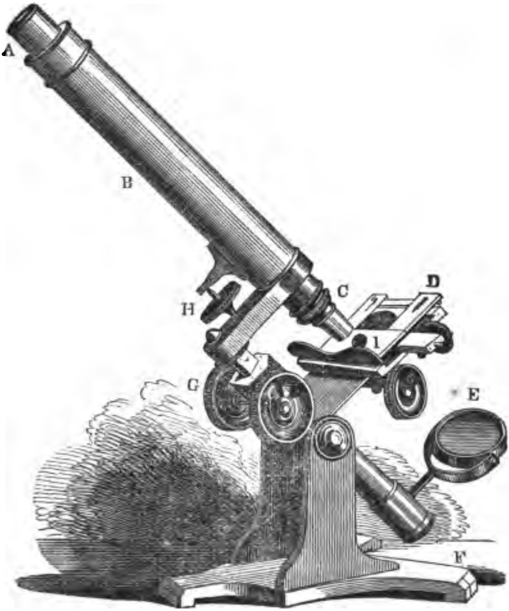
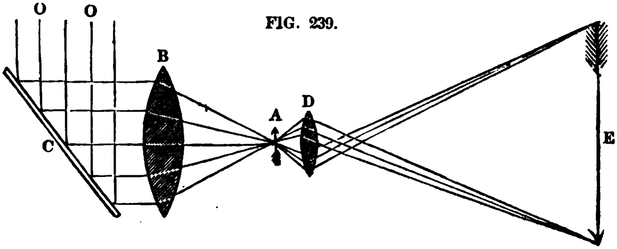
83. How many lenses has the solar microscope? Why is one of the lenses of the solar microscope called the condenser?

FIG. 238.



Compound Microscope, Complete.

FIG. 239.



Solar Microscope.

direction, and which reflects the rays of the sun on the cc- denser.

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83. Describe the uses of the two lenses and the reflector. Is the object, or only the shadow, seen by this instrument ?

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The object, A, *Fig.* 239, being placed nearly in the focus of the condenser, B, is strongly illuminated, in consequence of the rays of the sun being thrown on B, by the mirror, C. The object is not placed exactly in the focus of the condenser, because, in most cases, it would soon be destroyed by its heat, and because the focal point would illuminate only a small extent of surface, but may be exactly in the focus of the small lens, D, by which no such accident can happen. The lines, O O, represent the incident rays of the sun, which are reflected on the condenser.

When the solar microscope is used, the room is darkened, the only light admitted being that which is thrown on the object by the condenser, which light passing through the small lens, gives the magnified shadow, E, of the small object, A, on the wall of the room, or on a screen. The tube containing the two lenses is passed through the window of the room, the reflector remaining outside.

In the ordinary use of this instrument, the object itself is not seen, but only its shadow on the screen, and it is not designed for the examination of obaque objects.

When the small lens of the solar microscope is of great magnifying power, it presents some of the most striking and curious of optical phenomena. The shadows of mites from cheese, or figs, appear nearly two feet in length, presenting an appearance exceedingly formidable and disgusting; and the insects from common vinegar appear eight or ten feet long, and in perpetual motion, resembling so many huge serpents.

TELESCOPE.

84, *The Telescope is an optical instrument, employed to view distant bodies, and in effect to bring them nearer the eye, by increasing the apparent angles under which such objects are seen.*

These instruments are of two kinds, namely, *refracting* and *reflecting* telescopes. In the first kind. the image of the object is seen with the eye directed toward it; in the second kind, the image is seen by reflection from a mirror, while the back is toward the object, or by a double reflection, with the face toward the object.

The telescope is the most important of all optical instruments, since it unfolds the wonders of other worlds, and gives us the means of calculating the distances of the heavenly bodies, and

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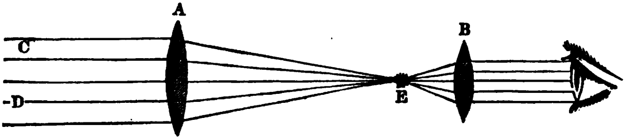
84. What is a telescope? How many kinds of telescopes are mentioned? What is the difference between them? In what respect does the refracting telescope differ from the compound microscope?

of explaining their phenomena for astronomical and nautical purposes.

The principle of the telescope will be readily comprehended after what has been said concerning the compound microscope, for the two instruments differ chiefly in respect to the place of the object lens, that of the microscope having a short, while that of the telescope has a long, focal distance.

85. Refracting Telescope.—The most simple refracting telescope consists of a tube, containing two convex lenses, the one having a long, and the other a short focal distance. (The focal distance of a double convex lens, it will be remembered, is nearly the center of the sphere, of which it is a part. 56.) These two lenses are placed in the tube, at a distance from each other equal to the sums of their two focal distances.

FIG. 240.



Principle of the Telescope.

Thus, if the focus of the object glass, A, *Fig.* 240, be eight inches, and that of the eye-glass, B, two inches, then the distance of the sums of the foci will be ten inches, and, therefore, the two lenses must be placed ten inches apart; and the same rule is observed, whatever may be the focal lengths of any two lenses.

Now, to understand the effect of this arrangement, suppose the rays of light, C D, coming from a distant object, as a star, to fall on the object glass, A, in parallel lines, and to be refracted by the lens to a focus at E, where the image of the star will be represented. The image is then magnified by the eye-glass, B, and thus, in effect is brought near the eye.

All that is effected by the telescope, therefore, is to form an image of a distant object, by means of the object lens, and then to assist the eye in viewing this image as nearly as possible by the eye lens.

It is, however, necessary here to state, that by the last figure,

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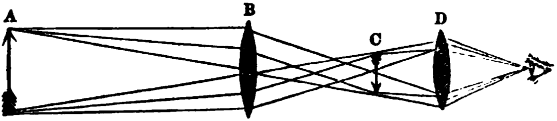
85. How is the most simple refracting telescope formed? Which is the object, and which the eye lens, in Fig. 240? What is the rule by which the distance of the two glasses apart is found? How do the two glasses act, to bring an object near the eye? Explain Fig. 241, and show how the object comes to be inverted by the two lenses

the principle only of the telescope is intended to be explained, for in the common instrument, with only two glasses the image appears to the eye inverted.

The reason of this will be seen by the next figure, where the direction of the rays of light will show the position of the image.

FIG. 241.



Principle of the Telescope.

Suppose A, *Fig.* 241, to be a distinct object from which pencils of rays flow from every point toward the object-lens, B. The image of A, in consequence of the refraction of the rays by the object lens, is inverted at C, which is the focus of the eye-glass, D, and through which the image is then seen, still inverted.

86. *Spy-glass.*—The inversion of the object is of little consequence when the instrument is employed for astronomical purposes, for since the forms of the heavenly bodies are spherical, their positions, in this respect, do not affect their general appearance. But for terrestrial purposes, this is manifestly a great defect, and therefore those constructed for such purposes, as ship, or spy-glasses, have two additional lenses, by means of which, the images are made to appear in the same position as the objects. These are called double telescopes.

Such a telescope is represented at *Fig.* 242, and consists of an object glass, and three eye-glasses, B C and D. The eye-glasses are placed at equal distances from each other, so that the focus of one may meet that of the other, and thus the image formed by the object lens, will be transmitted through the other three lenses to the eye. The rays coming from the object, O, cross each other at the focus of the object lens, and thus form an inverted image at F. This image being also in the focus of the first eye-glass, B, the rays having passed through this glass become parallel, for we have seen in another place, that diverging rays are rendered parallel by refraction through a convex lens. The rays, therefore, pass parallel to the next lens,

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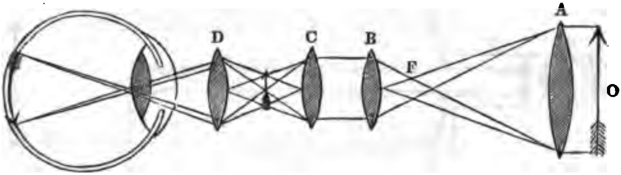
86. How is the inversion of the object corrected? Explain Fig. 242, and show why the two additional lenses make the image of the object erect. Does the addition of these two lenses make any difference with the apparent magnitude of the object.

C, by which they are made to converge, and cross each other, and thus the image is inverted, and made to assume the original position of the object, O. Lastly, this image, being in the focus of the eye-glass, D, is seen in the natural position.

FIG. 242.



Refracting Telescope.

The apparent magnitude of the object is not changed by these two additional glasses, but depends, as in *Fig.* 240, on the magnifying power of the eye and object lenses; these two glasses being added merely for the purpose of making the image appear erect.

87. Reflecting Telescope.—The common reflecting telescope consists of a large tube, containing two concave reflecting mirrors, of different sizes, and two eye-glasses. The object is first reflected from the large mirror to the small one, and from the small one, through the two eye-glasses, where it is then seen.

In comparing the advantages of the two instruments, it need only be stated, that the refracting telescope with a focal length of a thousand feet, if it could be used, would not magnify distinctly more than a thousand times, while a reflecting telescope, only eight or nine feet long, will magnify with distinctness twelve hundred times.

The principle and construction of the reflecting telescope will be understood by *Fig.* 243. Suppose the object, O, to be at such a distance, that the rays of light from it pass in parallel lines, P P, to the great reflector, R R. This reflector being concave, the rays are converged by reflection, and cross each other at A, by which the image is inverted. The rays then pass to the small mirror, B, which being also concave, they are thrown back in nearly parallel lines, and having passed the aperture in the center of the great mirror, fall on the plano-convex lens, E. By this lens they are refracted to a focus, and

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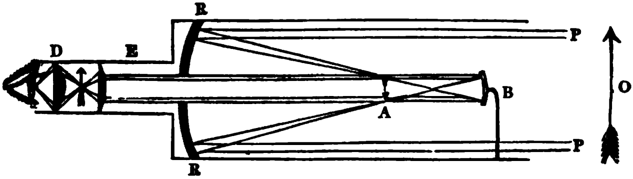
87. How many lenses and mirrors form the reflecting telescope? What are the advantages of the reflecting over the refracting telescope? Explain Fig. 243, and show the course of the rays from the object to the eye. Why is the small mirror in this instrument made to move by means of a screw?

cross each other between E and D, and thus the image is again inverted, and brought to its original position, or in the position of the object. The rays then passing the second eye-glass, form the image of the object on the retina.

FIG. 243.



Reflecting Telescope.

The large mirror in this instrument is fixed, but the small one moves backward and forward, by means of a screw, so as to adjust the image to the eyes of different persons. Both mirrors are made of a composition, consisting of several metals melted together.

88. One great advantage which the reflecting telescope possesses over the refracting, appears to be, that it admits of an eye-glass of shorter focal distance, and, consequently, of greater magnifying power. The convex object glass of the refracting instrument, does not form a perfect image of the object, since some of the rays are dispersed, and others colored by refraction. This difficulty does not occur in the reflected image from the metallic mirror of the reflecting telescope, and consequently it may be distinctly seen, when more highly magnified.

The instrument just described is called "*Gregory's telescope,*" because some parts of the arrangement were invented by Dr. Gregory.

89. LORD ROSSE'S TELESCOPE.—Dr. Herschel's telescope was the largest ever constructed until recently, when a young nobleman of fortune in Ireland, Lord Rosse, being led by an inventive genius, and having, it appears, a degree of enterprise not to be deterred by difficulties, projected the plan of building a telescope of a size and power hitherto unknown in the world.

The following account of the "Monster Telescope," as it has been called, is taken from that of Thomas Dick, LL. D., contained in his works.

It appears that the possibility of casting a speculum, or

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88. What is the advantage of the reflecting telescope in respect to the eye-glass? 89. Who constructed the largest telescope in the world? What is the size of the speculum?

reflector for a telescope, of six feet in diameter, was entertained by his lordship in 1840, though others considered such an undertaking in the light of a chimera. But the trial being made through the perseverance and large expenditures of the projector, complete success crowned the experiment, a nearly perfect casting of a speculum 72 inches in diameter being the result. Thus the difficulty of constructing an instrument one-third larger than Herschel's, was at once surmounted.

90. *Composition and Casting.*—The composition of this speculum is *copper and tin* united very nearly in their atomic proportions, namely: copper 126.4, to tin 58.9 parts. A foundry was constructed expressly for this great casting, the chimney of which was 18 feet high, and 16½ feet square at the foundation. The crucibles for containing the fused alloy were of cast iron, 2 feet in diameter, and 2½ feet deep. Iron baskets, suspended by cranes, were so contrived as to receive the crucibles and their melted contents, and swing them to the mould into which, one after the other, they were poured. The mould, 6 feet in diameter, and 5½ inches deep, was arranged in an exact horizontal position by means of spirit levels. The crucibles were 10 hours in the furnace before the metal was sufficiently fluid to cast. The speculum weighed 3 tons—lost one-eighth of an inch in thickness by grinding.

Construction of the Tube.—The tube is 56 feet long, made of boards and hooped with iron. On the inside at intervals of 8 feet, are iron rings to support the boards. Its diameter is 7 feet, the whole being easily moved in any direction by means of pulleys and levers, a universal joint at the lower end being designed for this purpose.

Wall of Support.—At a distance of 12 feet, on each side of the instrument is a brick wall, 72 feet long, 48 high on the outside, and 56 on the inside, ranging exactly on the meridional line. These walls have rods of iron and wood passing from one to the other, for the support of the telescope, as it is turned in different directions.

The weight of the speculum and tube, including that of the bed on which it is sustained, is about 15 tons.

This being a reflecting telescope, the observer stands in a gallery at the upper end, and looks into the side of the great tube, where the observations are made by means of a reflecting surface of 4,071 square inches, while Herschel's great reflector had a surface of only 1,811 square inches.

The cost of this wonder of the age is 60,000 dollars.

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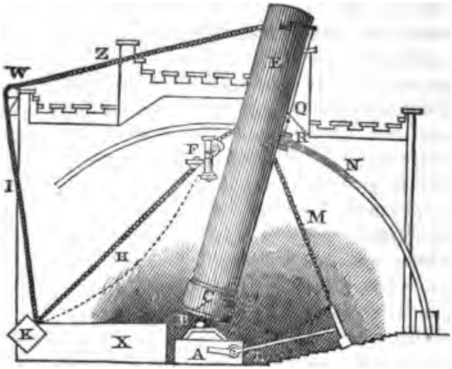
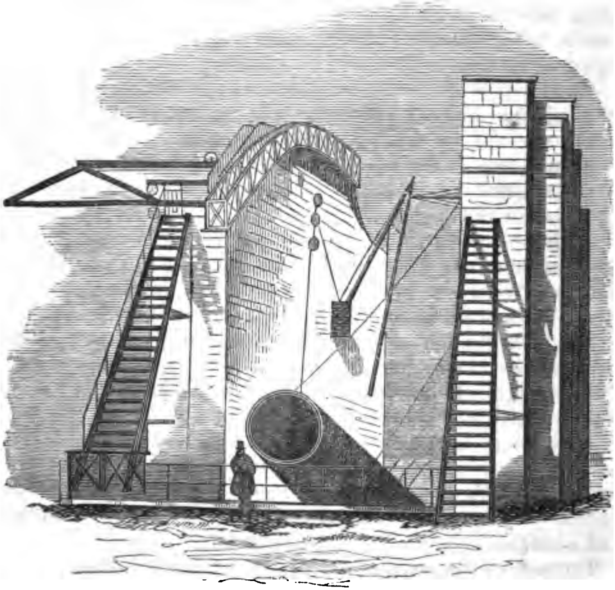
90. What is its composition? How much larger is this instrument than Herschel's?

FIG. 244.



Outline of Lord Rosse's Telescope.

FIG. 245.

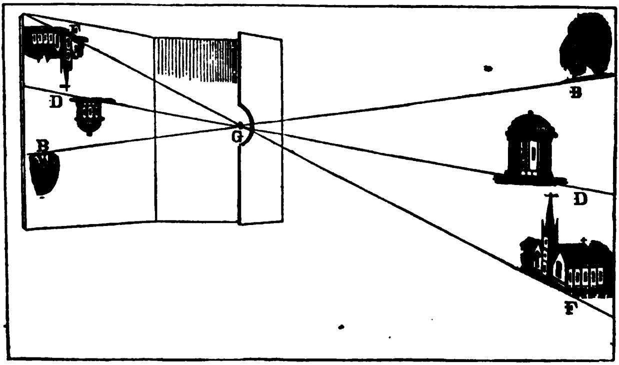


Lord Rosse's Telescope,—complete.

Description of the Figure.—The following description of a section of Lord Rosse's telescope, *Fig.* 244, though not so perfect as could be desired, is the best we could obtain. It exhibits a view of the inside of the eastern wall, with the tube, and machinery by which it is moved. A is the mason-work on the ground; B the universal joint, which allows the tube to turn in all directions; C the speculum in the tube; E the eyepiece through which the observer looks; F a pulley by which the tube is moved; H a chain attached to the pulley, and to the side of the tube; I a chain running to K, to counterpoise; L a lever connecting the chain M, with the tube; Z another chain which passes from the upper part of the tube over a pulley at W, (not seen,) and crosses to the opposite wall; X a railroad on which the speculum is drawn either to or from the tube. The dotted line, H, shows the course of the weight, R, as the tube rises or falls. The tube is moved from wall to wall by a ratchet wheel at R, which is turned by the lever, O, on the circle, N, the ends of which are fixed in the two walls.

91. Camera Obscura.—*Camera obscura strictly signifies a darkened chamber, because the room must be darkened, in order to observe its effects.*

FIG. 246.



Principle of the Camera.

To witness the phenomena of this instrument, let a room be closed in every direction, so as to exclude the light. Then from

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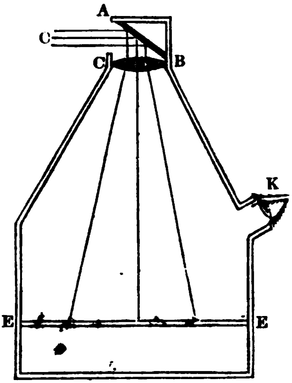
91. What does camera obscura mean? Describe the phenomena of the camera obscura

an aperture, say of an inch in diameter, admit a single beam of light, and the images of external things, such as the trees and houses, and persons walking the streets, will be seen inverted on the wall opposite to where the light is admitted, or on a screen of white paper, placed before the aperture.

92. The reason why the image is inverted will be obvious, when it is remembered that the rays proceeding from the extremities of the object must converge in order to pass through the small aperture; and as the rays of light always proceed in straight lines, they must cross each other at the point of admission, as explained under the article *Vision*.

Thus the pencil, B, *Fig.* 246, coming from the foot of the tree, and proceeding straight, will represent the image of that part at B, while the lower part, D, for the same reason, will be represented at D. If a convex G lens, with a short tube, be placed in the aperture through which the light passes into the room, the images of things will be much more perfect, and their colors more brilliant.

FIG. 247



A Camera Obscura

This instrument is sometimes employed by painters, in order to obtain an exact delineation of a landscape, an outline of the image being easily taken with a pencil, when the image is thrown on a sheet of paper.

There are several modifications of this machine, and among them the *revolving* camera obscura is the most interesting.

It consists of a small house, *Fig.* 247, with a plane reflector, A B, and a double-convex lens C B, placed at its top. The reflector is fixed at an angle of 45 degrees with the horizon, so as to reflect the rays of light perpendicularly downward, and is made to revolve quite around, in either direction, by pulling a string.

Now suppose the small house to be placed in the open air, with the mirror, A B, turned toward the east, then the rays of light flowing from the objects in that direction, will strike the

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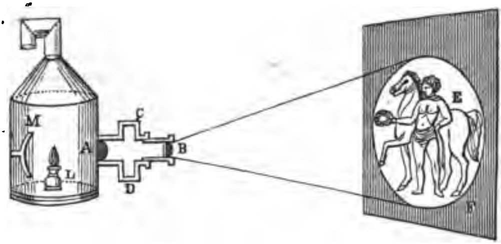
92. Why is the image formed by the camera obscura inverted? How may an outline of the image formed by the camera obscura be taken? Describe the revolving camera obscura.

mirror in the direction of the lines, O, and be reflected down through the convex lens, C B, to the table, E E, where they will form in miniature a most perfect and beautiful picture of the landscape in that direction. Then, by making the reflector revolve, another portion of the landscape may be seen, and thus the objects, in all directions, can be viewed at K without changing the place of the instrument.

MAGIC LANTERN.

93. *The Magic Lantern is a microscope on the same principle as the solar miscrscope.*—But instead of being used to magnify natural objects, it is commonly employed for amusement, by casting the shadows of small transparent paintings done on glass, upon a sereen placed at a proper distance.

FIG. 248.



Magic Lantern.

94. *Description.*—For the purpose in question the lamp, L, is included in a dark lantern, and behind the lantern is the metallic concave reflector, M, and in front of this is placed a large plano-convex lens, A. In the tube of the lantern, at C, is a groove to receive the pictures. These are of various colors, of thin stuff, so that the light may shine through them, and thus show groups of men and animals, in their proper costumes, on the white screen, E F. The lens, B, is moveable by a screw so as to adjust the focus to the distance required.

CHROMATICS, OR THE PHILOSOPHY OF COLORS.

95. We have thus far considered light as a simple body, and have supposed that all its parts were equally refracted, in its

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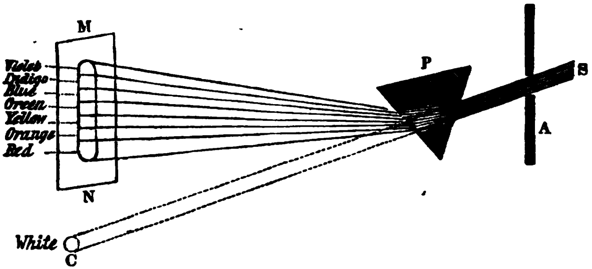
93. What is the magic lantern? For what purpose is this instrument employed? Describe the construction and effect of the magic lantern. 95. Who made the discovery that light is a compound substance?

passage, through the several lenses described. But it will now be shown that light is a compound body, and that each of its rays, which to us appear white, is composed of several colors, and that each color suffers a different degree of refraction, when the rays of light pass through a piece of glass, of a certain shape. This was a discovery of Sir Isaac Newton.

96. Solar Spectrum.—If a ray, proceeding from the sun, be admitted into a darkened chamber, through an aperture in the window shutter, and allowed to pass through a triangular shaped piece of glass, called a *prism*, the light will be decomposed, and instead of a spot of white, there will be seen, on the opposite wall, a most brilliant display of colors, including all those seen in the rainbow.

FIG. 249.



Solar Spectrum.

Suppose S, *Fig.* 249, to be a ray from the sun, admitted through the window shutter, A, in such a direction as to fall on the floor at C, where it would form a round, white spot. Now, on interposing the prism, P, the ray will be refracted, and at the same time decomposed, and will form on the screen, M N, an oblong figure, containing seven colors, which will be situated in respect to each other, as named on the figure.

It may be observed, that of all the colors the red is *least* refracted, or is thrown the smallest distance from the direction of the original sunbeam, and that the violet is *most* refracted, or bent out of that direction.

This oblong image containing the colored rays, is called the *solar* or *prismatic spectrum*.

97. *Recomposition of White Light.*—That the rays of the

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96. In what manner, and by what means, is light decomposed? What are the prismatic colors, and how do they succeed each other in the spectrum? Which color is refracted most and which least?

sun are composed of the several colors above named, is sufficiently evident by the fact, that such a ray is divided into these several colors by passing through the prism, but in addition to this proof, it is found by experiment, that if these several colors be blended or mixed together, white will be the result.

This may be done by mixing together seven powders whose colors represent the prismatic colors, and whose quantities are to each other, as the spaces occupied by each color in the spectrum. When this is done, it will be found that the resulting color will be a grayish white. A still more satisfactory proof that these seven colors form white, when united, is obtained by causing the solar spectrum to pass through a lens, by which they are brought to a focus, when it is found that the focus will be the same color as it would be from the original rays of the sun.

98. *Other Means of Decomposing Light.*—The prism is not the only instrument by which light can be decomposed. A soap bubble blown up in the sun will display most of the prismatic colors. This is accounted for by supposing that the sides of the bubbles vary in thickness, and that the rays of light are decomposed by these variations. The unequal surface of *mother of pearl*, and many other shells, send forth colored rays on the same principle.

Two surfaces of polished glass, when pressed together, will also decompose the light. Rings of colored light will be observed around the point of contact between the two surfaces, and their number may be increased or diminished by the degrees of pressure. Two pieces of common looking-glass, pressed together with the fingers, will display most of the prismatic colors.

99. A variety of substances, when thrown into the form of the triangular prism, will decompose the rays of light, as well as a prism of glass. A very common instrument for this purpose is made by putting together three pieces of plate glass, in form of a prism. The ends may be made of wood, and the edges cemented with putty, so as to make the whole water-tight. When this is filled with water, and held before a sunbeam, the solar spectrum will be formed, displaying the same colors, and in the same order as that above described.

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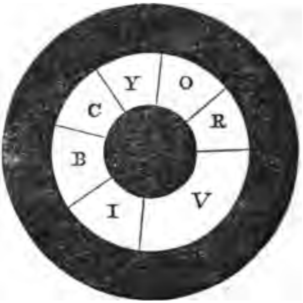
97. When the several prismatic colors are blended, what color is the result? When the solar spectrum is made to pass through a lens, what is the color of the focus? How do we learn that each colored ray has a refractive power of its own? 98. By what other means besides the prism, can the rays of light be decomposed? How may light be decomposed by two pieces of glass? 99. Of what substance may prisms be formed, besides glass?

100. *Recomposition of Light by a Circle.*—On this subject, a curious and satisfactory experiment may be made by means of a dark center, and circle, with divisions between them, representing the proportions of the prismatic rays, and colored to imitate them. The letters, *Fig.* 250, show the different colors of the seven rays, and the spaces they severally occupy.

101. Now if this card, thus colored, be placed on a spindle and made to turn rapidly, the seven colors will entirely disappear, and a dull white only will be presented to the eye, instead of them.

FIG. 250.



Recomposition of Light.

102. *Explanation*—Any color remains for an instant on the eye after it is covered, or removed, and hence a fire-brand whirled rapidly appears a circle of fire. Two revolving colors will thus be so blended as to seem a medium between them; thus if all the colors on the card are covered, except the yellow and red, they will appear orange. And if all the prismatic tints are blended, whether in the form of powder, or proportionate colored, revolving surfaces, they produce white.

THE RAINBOW.

103. The rainbow was a phenomenon, for which the ancients were entirely unable to account; but after the discovery that light is a compound principle, and that its colors may be separated by various substances, the solution of this phenomenon became easy.

Sir Isaac Newton, after his great discovery of the compound nature of light, and the different refrangibility of the colored rays, was able to explain the rainbow on optical principles.

104. If a glass globe be suspended in a room, where the rays of the sun can fall upon it, the light will be decomposed, or separated into several colored rays, in the same manner as is

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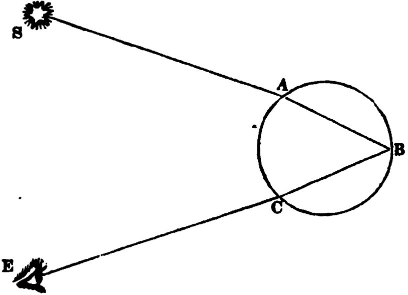
100. For what are the divisions of the circle, Fig. 250, intended? What is said to be the effect when this card is revolved on a spindle? 101. What color is said to be produced when all the prismatic tints are mixed or revolved? 102. What is the explanation? What discovery preceded the explanation of the rainbow? Who first explained the rainbow on optical principles? 104. Why does not a glass globe form a well defined spectrum? From which surface do transparent bodies chiefly reflect the light?

done by the prism. A well defined spectrum will not, however, be formed by the globe, because its shape is such as to disperse some of the rays, and converge others; but the eye, by taking different positions in respect to the globe, will observe the various prismatic colors. Transparent bodies, such as glass and water, reflect the rays of light from both their surfaces, but chiefly from the second surface. That is, if a plate of naked glass be placed so as to reflect the image of the sun, or of a lamp, to the eye, the most distinct image will come from the second surface, or that most distant from the eye. The great brilliancy of the diamond is owing to this cause. It will be understood directly, how this principle applies to the explananation of the rainbow.

FIG. 251.



How the Bow is Formed.

105. *How the Bow is Formed.*— Suppose the circle, A B C, *Fig.* 251, to represent a globe, or a drop of rain, for each drop of rain, as it falls through the air, is a small globe of water. Suppose also, that the sun is at S, and the eye of the spectator at E. Now, it has already been stated, (104,) that from a single globe, the whole solar spectrum is not seen in the same position, but that the different colors are seen from different places. Suppose, then, that a ray of light from the sun, S, on entering the globe at A, is separated into its primary colors, and at the same time the red ray, which is the least refrangible, is refracted in the line from A to B. From the second, or inner surface of the drop, it would be reflected to C, the angle of reflection being equal to the angle of incidence. On passing out of the drop, its refraction at C, would be just equal to the refraction of the incident ray at A, and therefore the red ray would fall on the eye at E. All the other colored rays would follow the same law, but because the angles of incidence and those of reflection are equal, and because the colored rays are separated from each other by unequal

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105. Explain Fig. 251, and show the different refractions, and the reflection concerned in forming the rainbow. In the case supposed, why will only the red ray meet the eye? Suppose a person looking at the rainbow, moves his eye, will he see the same colors from the same drop of rain?

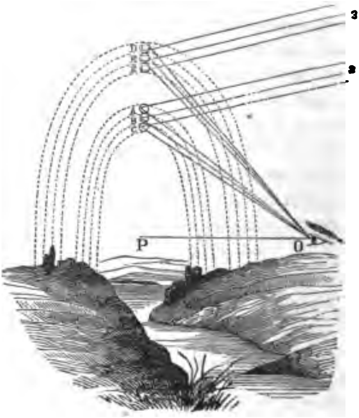
refraction, it is obvious, that if the red ray enters the eye at E, none of the other colored rays could be seen from the same point.

But in a shower of rain, there are drops at all heights and distances, and though they perpetually change their places, in respect to the sun and the eye, as they fall, still there will be many which will be in such a position as to reflect the red rays to the eye, and as many more to reflect the yellow rays, and so of all the other colors.

106. *The Rainbow Complete.*—This will be made obvious by *Fig.* 252, where, to avoid confusion, we will suppose that only three drops of rain, and, consequently, only three colors are to be seen.

The numbers, 3 3, are the rays of the sun, proceeding to the drops, A B C, and from which these rays are reflected to the eye, making different angles with the horizontal line, O P, because one colored ray is refracted more than another. Now, suppose the red ray only reaches the eye from the drop, A, the green from the drop, B, and the violet from the drop, C, then the spectator would see a minute rainbow of three colors. But during a shower of rain, all the drops which are in the position of A, in respect to the eye, would send forth red rays, and no other, while those in the position of B, would emit green rays, and no other, and those in the position of C, violet rays; and so of all the other prismatic colors. Each circle of colors, of which the rainbow is formed, is therefore composed of reflections from a vast number of different drops of rain, and the reason why these colors are distinct to our senses, is that we see only one color from a single drop, with the eye in the same position. It follows, then, that if we change our position, while look-

FIG. 252.



Rainbow.

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106. Explain Fig. 252, and show why we see different colors from different drops of rain. Do several persons see the same rainbow at the same time? Explain the reason of this.

ing at a rainbow, we still see a bow, but not the same as before, and hence, if there are many spectators, they will all see a different rainbow, though it appears to be the same.

The letters, D E F, represent the secondary bow, which is always paler than the primary, because in this the rays of light suffer two refractions, and two reflections, while in the primary there are two refractions, but only one reflection.

COLORS OF OBJECTS.

107. *Color Depends on Absorption and Reflection.*—It appears that the colors of all bodies depend on some peculiar property of their surfaces, in consequence of which, they absorb some of the colored rays, and reflect the others. Had the surfaces of all bodies the property of reflecting the same ray only, all nature would display the monotony of a single color, and our senses would never have known the charms of that variety which we now behold.

108. To account for such a variety of colors as we see in different bodies, it is supposed that all substances, when made sufficiently thin, are transparent, and, consequently, that they transmit through their surfaces, or absorb, certain rays of light, while other rays are thrown back, or reflected. Gold, for example, may be beat so thin as to transmit some of the rays of light, and the same is true of several of the other metals, which are capable of being hammered into thin leaves. It is, therefore, most probable, that all the metals, could they be made sufficiently thin, would permit the rays of light to pass through them. Most, if not quite all mineral substances, though, in the mass, they may seem quite opaque, admit the light through their edges, when broken, and almost every kind of wood, when made no thinner than writing-paper, becomes translucent. Thus, we may safely conclude, that every substance with which we are acquainted, will admit the rays of light, when made sufficiently thin.

109. *Transparent Substances.*—Transparent, colorless substances, whether solid or fluid, such as glass, water, or mica, reflect and transmit light of the same color; that is, the light seen through these bodies, and reflected from their surfaces, is white. This is true of all transparent substances under ordinary circumstances; but, if their thickness be diminished to a certain

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107. On what do the colors of bodies depend? Suppose all bodies reflected the same ray, what would be the consequence in regard to color? 108. How is the variety of colors accounted for, by considering all bodies transparent? 109. What is said of the reflection of colored light by transparent substances?

extent, these substances will both reflect and transmit colored light of various hues, according to their thickness. Thus, the thin plates of mica, which are left on the fingers after handling that substance will reflect prismatic rays of various colors.

110. From such phenomena Sir Isaac Newton concluded, that air, when below the thickness of *half a millionth of an inch* ceases to reflect light; and, also, that water when below the thickness of *three-eighths of a millionth of an inch*, ceases to reflect light. But, that both air and water, when their thickness is, in a certain degree, above these limits, reflect all the colored rays of the spectrum.

111. From a great variety of experiments on this subject, Sir Isaac Newton concludes that the transparent parts of bodies, according to the sizes of their transparent pores, reflect rays of one color, and transmit those of another, for the same reason that thin plates, or minute particles of air, water, and some other substances, reflect certain rays, and absorb or transmit others, and that this is the cause of all their colors.

CHAPTER XII.

ASTRONOMY.

112. This term is compounded of the Greek *astra*, the stars, and *nomos*, a law; and, hence, signifies the laws of the celestial bodies.

Astronomy is that science which treats of the motions and appearance of the heavenly bodies; accounts for the phenomena which these bodies exhibit to us; and explains the laws by which their motions, or apparent motions, are regulated.

Astronomy is divided into *Descriptive*, *Physical*, and *Practical.*

Descriptive astronomy demonstrates the magnitudes, distances, and densities of the heavenly bodies, and explains the phenomena dependent on their motions, such as the change of seasons, and the vicissitudes of day and night.

Physical astronomy explains the theory of planetary motion, and the laws by which this motion is regulated and sustained.

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109. What substance is mentioned as illustrating this fact? 110. What is the conclusion of Sir Isaac Newton concerning the tenuity at which water and air cease to reflect light? 111. What is said of the porous nature of the solid bodies? 112. What is astronomy? How is astronomy divided? What does descriptive astronomy teach? What is the object of physical astronomy?

Practical astronomy details the description and use of astronomical instruments, and develops the nature and application of astronomical calculations.

The heavenly bodies are divided into three distinct classes, or systems, namely, *the solar system*, consisting of the sun, moon, and planets; the system of the *fixed stars;* and the system of the *comets.*

THE SOLAR SYSTEM.

113. *The Solar System consists of the Sun, and sixty-three other bodies, including the satellites, which revolve around him at various distances, and in various periods of time.*

These bodies, being perpetually in motion, are called *planets*, from a Greek word, signifying wanderers, and they are distinguished, with reference to their centers of revolution, into *primary* and *secondary.*

114. The *Primary* planets are those which revolve around the sun, as their proper center. These are twelve in number; that nearest the sun being Mercury, the others follow in succession, thus: Venus, Earth, Mars, Vesta, Ceres, Pallas, Juno, Jupiter, Saturn, Herschel or Uranus, and Neptune.

115. The *Secondary* planets are those which move round the primaries, as these move round the sun. Of these, there are twenty, called also *moons*, or *satellites.* These, as we shall see, like their primaries, complete their revolutions at various periods of time.

PRIMARY PLANETS.

Names of the Planets,	Diameter in English miles.	Distances from the Sun in English miles.	Revolution round the Sun.	Periods of revolution on their own axes.			Hourly motion in miles.
			Days.	Days.	Hrs.	M.	
Mercury,	3,224	37,000,000	88	15	0	5	110,000
Venus,	7,687	68,000,000	224¼	0	23	21	80,000
The Earth,	7,912	95,000,000	365¼	1	0	0	68,000
Mars,	4,189	144,000,000	687	1	0	39	55,000
Vesta,	238	225,000,000	1,335	Unknown.			45,000
Ceres,	163	260,000,000	1,681				41,000
Pallas,	80	266,000,000	1,680				41,000
Juno,	1,425	275,000,000	2,008	1	3	0	45,000
Jupiter,	89,170	490,000,000	4,330½	0	9	56	36,000
Saturn,	79,042	900,000,000	10,746¼	0	10	16	22,000
Herschel,	35,112	1,800,000,000	30,637¼	0	7	0	15,000
Neptune,	35,000	2,850,000,000	166 ys.	Unknown.			Unknown.

NOTE.—The above table, taken from the last London (Prof. Hoblyn's) edition of our Philosophy, is believed to be correct, according to the most recent observations. It will

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112. What is practical astronomy? How are the heavenly bodies divided? 113. Of what does the solar system consist? 114. What are the bodies called which revolve around the Sun as a center? 115. What are those planets called which revolve around these primaries as a center?

be seen that, in the descriptions of the planets, round numbers are generally employed, as being more easily remembered; also, that the periodic revolutions of the planets are given in years, days, and hours, instead of days only, as in the table.

116. The foregoing tabular view of the primary planets exhibits their respective diameters; their distances from the sun; the periods of their revolutions round the sun; the periods of their revolutions round their axes, where this is known; and their hourly motion through their several orbits.

117. *A Year, what.*—A year consists of the time which it takes a planet to perform one complete revolution through its orbit, or, to pass once around the Sun. Our Earth performs this revolution in about 365 days, and, therefore, this is the period of our year. Mercury completes his revolution in 88 days, and, therefore, his year is no longer than 88 of our days. But, the planet Herschel is situated at such a distance from the Sun, that his revolution is not completed in less than about 84 of our years. The other planets complete their revolutions in various periods of time, between these; so that, the time of these periods is generally in proportion to the distance of each planet from the Sun.

118. Besides the above enumerated primary planets, our system contains twenty secondary planets, or moons. Of these, our Earth has one moon, Jupiter four, Saturn eight, and Herschel six. None of these moons, except our own, and one or two of Saturn's, can be seen without a telescope. The seven other planets, so far as has been discovered, are entirely without moons.

119. All the planets move around the sun, from west to east and, in the same direction do the moons revolve around their primaries, with the exception of those of Herschel, which appear to revolve in a contrary direction.

NEW PLANETS AND ASTEROIDS.

With the exception of Uranus, or Herschel, and Neptune, these planets are called *Asteroids*, meaning *star-like*, or more recently, *Planetoids*, planet-like, on account of their diminutive sizes, and, in order to distinguish them from the larger planets.

120. Mr. Hind proposed Victoria, or Clio, for the name of the planet which he discovered on the 13th of September, and, at first, the name of the Queen was adopted by many foreign as-

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116. In what order are the several planets situated in respect to the Sun? How long does it take each planet to make its revolution around the Sun? 117. What is a year? 118. How many moons does our system contain? Which of the planets are attended by moons, and how many has each? 119. In what direction do the planets move around the Sun? 120. What is said with respect to the names of the planets?

tronomers. But, it seems that the scientific world have long since refused to name planets after their discoverers, or their patrons, or, indeed, after any mortal individual, choosing to adopt for them the names of heathen deities, thus following the ancient custom in this respect.

121. The following table contains the names of the new planets and asteroids, with the date, place of discovery, the name of the discoverer, and their distances from the sun.

Name of Planet.	Name of Discoverer.	Place of Discovery.	Mean Dista'ce from the Sun in Eng. miles.	Time of Discovery.
1. Ceres	Piazzi	Palermo	263,740,000	1801, January
2. Pallas	Olbers	Bremen	264,400,000	1802, March
3. Juno	Harding	Lilienthal	254,430,000	1804, September
4. Vesta	Olbers	Bremen	225,290,000	1807, March
5. Astræa	Hencke	Driesen	245,790,000	1845, December
6. Hebe	Hencke	Driesen	231,350,000	1847, July
7. Iris	Hind	London	227,550,000	1847, August
8. Flora	Hind	London	209,930,000	1847, October
9. Metis	Graham	Markree	227,580,000	1848, April
10. Hygeia	Gasparis	Naples	300,340,000	1849, April
11. Parthenope	Gasparis	Naples	233,810,000	1850, May
12. Victoria	Hind	London	222,650,000	1850, September
13. Egeria	Gasparis	Naples	245,880,000	1850, November
14. Irene	Hind	London	246,540,000	1851, May
15. Eunomia	Gasparis	Naples	252,090,000	1851, July
16. Psyche	Gasparis	Naples	278,710,000	1852, March
17. Thetis	Luther	Bilk	235,880,000	1852, April
18. Melpomene	Hind	London	218,930,000	1852, June
19. Fortuna	Hind	London	232,980,000	1852, August
20. Massilia	Gasparis	Naples	229,590,000	1852, September
21. Lutetia	Goldschmidt	Paris	232,240,000	1852, November
22. Calliope	Hind	London	277,870,000	1852, November
23. Thalia	Hind	London	250,420,000	1852, December
24. Themis	Gasparis	Naples	299,870,000	1853, April
25. Phocena	Chacornac	Marseilles	228,940,000	1853, April
26. Proserpine	Luther	Bilk	253,260,000	1853, May
27. Euterpe	Hind	London	223,770,000	1853, November
28. Bellona	Luther	Bilk	264,650,000	1854, March
29. Amphitrite	Marth	London	243,530,000	1854, March
30. Urania	Hind	London	228,020,000	1854, July
31. Euphrosyne	Ferguson	Washington	300,960,000	1854, September
32. Pomona	Goldschmidt	Paris	245,840,000	1854, October
33. Polyhymnia	Chacornac	Paris	274,820,000	1854, October
34. Circe	Chacornac	Paris	....	1855, April
35. Leucothea	Luther	Bilk	....	1855, April
36. Atalanta	Goldschmidt	Paris	....	1855, October
37. Fides	Luther	Bilk	....	1855, October

The preceding table is taken from the London Illustrated Almanac for 1856.

122. *Number of New or Recently Discovered Celestial Bodies.*—In our former edition, the solar system was stated to consist of the Sun and twenty-nine bodies revolving around him. At the present time, the number has increased to sixty-three, viz.,

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122. What number of revolving celestial bodies were formerly known? How many have recently been discovered, and what are they called?

the planet Neptune and thirty three Asteroids, names and dates of discovery of which are contained in the preceding table. It has been stated, also, that an eighth satellite of Saturn has been discovered; but, of this we have obtained no certain account. (*See errata.*)

The power and perfection of new astronomical instruments, will probably, lead to further celestial discoveries, of which the world at present can have no conception.

123. The radius of the Earth's orbit, in these computations, is assumed to be 95,000,000 of miles.

Observations.—The periods of the revolutions of many of the recently discovered Asteroids have not been determined. We have, therefore, allowed the old ones to remain in the table with the Planets, as in the former edition.

124. ORBITS OF THE PLANETS.—The paths in which the planets move round the Sun, and, in which the moons move round their primaries, are called their *orbits*. These orbits are not exactly circular, as they are commonly represented on paper, but are elliptical or oval, so that all the planets are nearer the Sun, when in one part of their orbits than when in another.

In addition to their annual revolutions, some of the planets are known to have diurnal or daily revolutions, like our Earth. The periods of these daily revolutions have been ascertained, in several of the planets, by spots on their surfaces. But, where no such mark is discernible, it can not be ascertained whether the planet has a daily revolution or not, though this has been found to be the case in every instance where spots are seen; and, therefore, there is little doubt but all have a daily as well as a yearly motion.

125. The *axis* of a planet is an imaginary line, passing through its center, and about which its diurnal revolution is performed. The *poles* of the planets are the extremities of this axis.

The orbits of Mercury and Venus are within that of the Earth, and, consequently, they are called *inferior* planets. The orbits of all the other planets are without, or exterior to that of the Earth, and these are called *superior* planets.

126. That the orbits of Mercury and Venus are within that of the Earth, is evident from the circumstance that they are never seen in opposition to the sun, that is, they never appear in the west when the Sun is in the east. On the contrary, the

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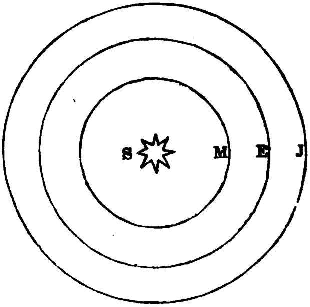
123. In the above table what is the estimated distance of the Sun? 124. What is the orbit of a planet? What revolutions have the planets, besides their yearly revolutions? Have all the planets diurnal revolutions? How is it known that the planets have daily revolutions? 125. What is the axis of a planet? What is the pole of a planet? Which are the superior, and which the inferior planets?

orbits of all the other planets are proved to be outside of the Earth's, since these planets are sometimes seen in opposition to the Sun.

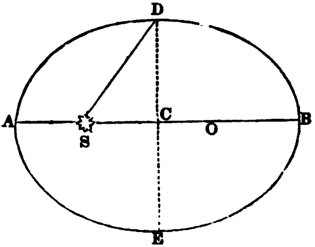
This will be understood by *Fig.* 253, where suppose S to be the Sun, M the orbit of Mercury or Venus, E the orbit of the Earth, and J that of Jupiter. Now, it is evident, that if a spectator be placed any where on the Earth's orbit, as at E, he may sometimes see Jupiter in opposition to the Sun, as at J, because then the spectator would be between Jupiter and the Sun. But the orbit of Venus, being surrounded by that of the Earth, she can never come in opposition to the Sun, or in that part of the heavens opposite to him, as seen by us, because our Earth never passes between her and the Sun.

FIG. 253.



Orbits of the Planets.

FIG. 254.



Eliptical Orbit.

127. *Orbits Elliptical.*—It has already been stated, that the orbits of the planets are elliptical, (124) and that, consequently, these bodies are sometimes nearer the Sun than at others. An ellipse, or oval, has two foci, and the Sun, instead of being in the common center, is always in the lower focus of his orbit.

The orbit of a planet is represented by *Fig.* 254, where A D B E is an ellipse, with its two foci, S and O, the Sun being in the focus, S, which is called the lower focus.

When the Earth, or any other planet, revolving round the Sun, is in that part of its orbit nearest the Sun, as at A, it is said to be in its *perihelion;* and when in that which is at the

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126. How is it proved that the inferior planets are within the Earth's orbit, and the superior ones without it? Explain Fig. 253, and show why the inferior planets never can be in opposition to the Sun. 127. What are the shapes of the planetary orbits? What is meant by perihelion? What by aphelion?

greatest distance from the Sun, as at B, it is said to be in its *aphelion.* The line, S D, is the mean, or average distance of a planet's orbit from the Sun.

128. Ecliptic.—The *planes* of the orbits of all the planets pass through the center of the Sun. The plane of an orbit is an imaginary surface, passing from one extremity, or side of the orbit, to the other. If the rim of a drum head be considered the orbit, its plane would be the parchment extended across it, on which the drum is beaten.

Let us suppose the Earth's orbit to be such a plane, cutting the Sun through his center, and extending out on every side to the starry heavens; the great circle so made, would mark the line of the *ecliptic*, or the Sun's apparent path through the heavens.

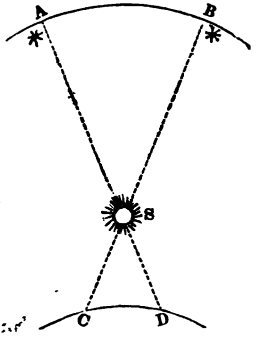
This circle is called the Sun's *apparent* path, because the revolution of the Earth gives the Sun the appearance of passing through it. It is called the ecliptic, because eclipses happen when the Moon is in, or near, this apparent path.

129. Zodiac.—*The Zodiac is an imaginary belt, or broad circle, extending quite around the heavens.* The ecliptic divides the zodiac into two equal parts, the zodiac extending 8 degrees on each side of the ecliptic, and therefore is 16 degrees wide. The zodiac is divided into 12 equal parts, called the *signs of the zodiac.*

130. The sun appears every year to pass around the great circle of the ecliptic, and consequently, through the 12 constellations, or signs of the zodiac. But it will be seen, in another place, that the Sun, in respect to the Earth, stands still, and that his apparent yearly course through the heavens is caused by the annual revolution of the earth around its orbit.

To understand the cause of this deception, let us suppose that S, *Fig.* 255, is the Sun, A B, a part of the circle of the ecliptic, and C D, a part of the Earth's orbit. Now if a spectator be placed at C, he will

FIG. 255.



Zodiac.

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128. What is the plane of an orbit? Explain what is meant by the ecliptic. Why is the ecliptic called the Sun's apparent path? 129. What is the zodiac? How does the ecliptic divide the zodiac? How far does the zodiac extend on each side of the ecliptic?

see the Sun in that part of the ecliptic marked by B, but when the Earth moves in her annual revolution to D, the spectator will see the Sun in that part of the heavens marked by A; so that the motion of the Earth in one direction, will give the Sun an apparent motion in the contrary direction.

131. CONSTELLATIONS.—A sign or *constellation*, is a collection of fixed stars, and as we have already seen, the Sun appears to move through the twelve signs of the zodiac every year. Now, the Sun's place in the heavens, or zodiac, is found by his apparent conjunction, or nearness to any particular star in the constellation. Suppose a spectator at C, *Fig.* 255, observes the Sun to be nearly in a line with the star at B, then the Sun would be near a particular star in a certain constellation. When the Earth moves to D, the Sun's place would assume another direction, and he would seem to have moved into another constellation, and near the star, A.

132. Each of the twelve signs of the zodiac is divided into 30 smaller parts, called degrees; each degree into 60 equal parts, called minutes, and each minute into 60 parts, called seconds.

The division of the zodiac into signs, is of very ancient date, each sign having also received the name of some animal, or thing, which the constellation, forming that sign, was supposed to resemble. It is hardly necessary to say, that this is chiefly the result of imagination, since the figures made by the places of the stars, never mark the outlines of the figures of animals, or other things. This is, however, found to be the most convenient method of finding any particular star at this day, for among astronomers, any star, in each constellation, may be designated by describing the part of the animal in which it is situated. Thus, by knowing how many stars belong to the constellation Leo, or the Lion, we readily know what star is meant by that which is situated on the Lion's ear or tail.

133. *Names of the Signs.*—The names of the 12 signs of the zodiac are, Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Aquarius, and Pices. The common names, or meaning of these words, in the same order, are, the Ram, the Bull, the Twins, the Crab, the Lion, the Virgin, the Scales, the Scorpion, the Archer, the Goat, the Waterer, and the Fishes.

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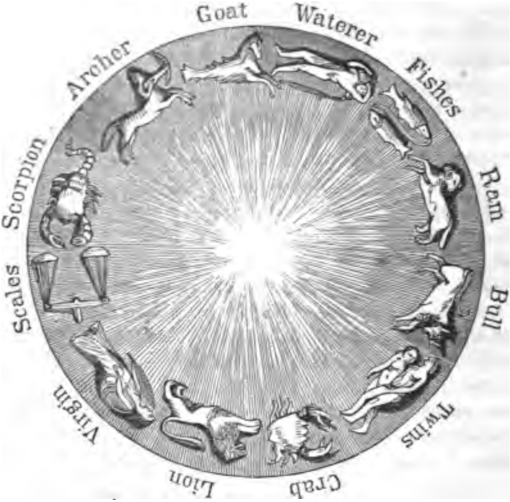
130. Explain Fig. 255, and show why the Sun seems to pass through the ecliptic, when the Earth only revolves around the Sun. 131. What is a constellation or sign? How is the Sun's apparent place in the heavens found? 132. Into how many parts are the signs of the zodiac divided, and what are these parts called? Is there any resemblance between the places of the stars, and the figures of the animals after which they are called? Explain why this is a convenient method of finding any particular star in a sign? 133. What are the names of the twelve signs?

FIG. 256.



Signs of the Zodiac.

134. *Figures of the Zodiac.*—The imaginary figures, representing the 12 Signs of the zodiac, are delineated in *Fig.* 256, with the rays of the Sun in the center.

135. DENSITY OF THE PLANETS.—Astronomers have no means of ascertaining whether the planets are composed of the same kind of matter as our Earth, or whether their surfaces are clothed with vegetables and forests, or not. They have, however, been able to ascertain the densities of several of them, by observations on their mutual attraction. By *density*, is meant compactness, or the quantity of matter in a given space. (72.) When two bodies are of equal bulk, that which weighs most, has the greatest density. It was shown, while treating of the *properties of bodies*, that substances attract each other in proportion to the quantities of matter they contain. (132.) If, therefore, we know the dimensions of several bodies, and can ascertain the proportion in which they attract each other, their quantities of matter, or densities, are easily found.

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135. How has the density of the planets been ascertained? What is meant by density? In what proportion do bodies attract each other?

136, Thus, when the planets pass each other in their circuits through the heavens, they are often drawn a little out of the lines of their orbits by mutual attraction. As bodies attract in proportion to their quantities of matter, it is obvious that the small planets, if of the same density, will suffer greater disturbance from this cause, than the large ones. But suppose two planets, of the same dimensions, pass each other, and it is found that one of them is attracted twice as far out of its orbit as the other, then, by the known laws of gravity, it would be inferred, that one of them contained twice the quantity of matter that the other did, and therefore that the density of the one was twice that of the other.

By calculations of this kind, it has been found, that the density of the Sun is but a little greater than that of water, while Mercury is more than nine times as dense as water, having a specific gravity nearly equal to that of lead. The Earth has a density about five times greater than that of the Sun, and a little less than half that of Mercury. The densities of the other planets seem to diminish in proportion as their distances from the Sun increase, the density of Saturn, one of the most remote of planets, being only about one-third that of water.

THE SUN.

137. *The Sun is the center of the solar system, and the great dispenser of heat and light to all the planets. Around the Sun all the planets revolve, as around a common center, he being the largest body in our system, and so far as we know, the largest in the universe.*

Distance of the Sun.—The distance of the Sun from the Earth is 95 millions of miles, and his diameter is estimated at 887,000 miles. Our globe, when compared with the magnitude of the Sun, is a mere point, for his bulk is about *thirteen hundred thousand* times greater than that of the Earth. Were the Sun's center placed in the center of the Moon's orbit, his circumference would reach two hundred thousand miles beyond her orbit in every direction, thus filling the whole space between us and the Moon, and extending nearly as far beyond her as she is from us. A traveller, who should go at the rate of 90 miles a day, would perform a journey of nearly 33,000

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136. How are the densities of the planets ascertained? What is the density of the Sun, of Mercury, and of the Earth? In what proportions do the densities of the planets appear to diminish? 137. Where is the place of the Sun in the solar system? What is the distance of the Sun from the Earth? What is the diameter of the Sun? Suppose the center of the Sun and that of the Moon's orbit to be coincident, how far would the Sun extend beyond the Moon's orbit?

miles in a year, and yet it would take such a traveller more than 80 years to go round the circumference of the Sun. A body of such mighty dimensions, hanging on nothing, it is certain, must have emanated from an Almighty power.

The Sun appears to move around the Earth every 24 hours, rising in the east, and setting in the west. This motion, as will be proved in another place, is only apparent, and arises from the diurnal revolution of the Earth.

138. *Diurnal Revolution of the Sun.*—The Sun, although he does not, like the planets, revolve in an orbit, is, however, not without motion, having a revolution around his own axis, once in 25 days and 10 hours. Both the fact that he has such a motion, and the time in which it is performed, have been ascertained by the spots on his surface. If a spot is seen, on a revolving body, in a certain direction, it is obvious, that when the same spot is again seen, in the same direction, that the body has made one revolution. By such spots the diurnal revolutions of the planets, as well as the Sun, have been determined.

139. SPOTS ON THE SUN.—Spots on the Sun seem first to have been observed in the year 1611, since which time they have constantly attracted attention, and have been the subject of investigation among astronomers. These spots change their appearance as the Sun revolves on his axis, and become greater or less, to an observer on the Earth, as they are turned to, or from him; they also change in respect to real magnitude and number; one spot, seen by Dr. Herschel, was estimated to be more than six times the size of our Earth, being 50,000 miles in diameter. Sometimes forty or fifty spots may be seen at the same time, and sometimes only one. They are often so large as to be seen with the naked eye; this was the case in 1816.

140. *Nature and design of these Spots.*—In respect to the nature and design of these spots, almost every astronomer has formed a different theory. Some have supposed them to be solid opaque masses of scoriæ, floating in the liquid fire of the Sun; others, as satellites, revolving round him, and hiding his light from us; others, as immense masses, which have fallen on his disc, and which are dark colored, because they have not yet become sufficiently heated. From these various theories we may infer that, at present, nothing certain is known of the nature and design of these spots.

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138. How is it proved that the Sun has a motion around his own axis? How often does the Sun revolve? 139. When were the spots on the Sun first observed? What has been the difference in the number of spots observed? What was the size of the spots seen by Dr. Herschel? 140. What has been advanced concerning the nature of these spots? Have they been accounted for satisfactorily?

MERCURY.

141. *Mercury*, the planet nearest the Sun, is about 3,000 miles in diameter, and revolves around him at the distance of 37 millions of miles. The period of his annual revolution is 88 days, and he turns on his axis once in about 15 hours.

No signs of an atmosphere have been observed in this planet. The Sun's heat at Mercury is about seven times greater than it is on the Earth, so that water, if nature follows the same laws there that she does here, can not exist at Mercury, except in the state of steam.

The nearness of this planet to the Sun, prevents his being often seen with the naked eye. He may, however, sometimes be observed just before the rising, and a little after the setting of the Sun. When seen after sunset, he appears a brilliant, twinkling star, showing a white light, which, however, is much obscured by the glare of twilight. When seen in the morning, before the rising of the Sun, his light is also obscured by the Sun's rays.

Mercury sometimes crosses the disc of the Sun, or comes between the Earth and that luminary, so as to appear like a small dark spot passing over the Sun's face. This is called the *transit* of Mercury.

VENUS.

142. *Venus* is the other planet, whose orbit is within that of the Earth. Her diameter is about 8,000 miles, being somewhat larger than the Earth.

Her revolution around the Sun is performed in 224 days, at the distance of 68 millions of miles from him. She turns on her axis once in 23 hours, so that her day is a little shorter than ours. Her hourly motion in her orbit, is 80,000 miles.

Venus, as seen from the Earth, is the most brilliant of all the primary planets, and is better known than any nocturnal luminary except the Moon. When seen through a telescope, she exhibits the phases or horned appearance of the moon, and her face is sometimes variegated with dark spots.

143. This planet may often be seen in the day time, even when she is in the vicinity of the blazing light of the Sun. A luminous appearance around this planet, seen at certain times,

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141. What is the diameter of Mercury, and what are his periods of annual and diurnal revolution? How great is the Sun's heat at Mercury? At what times is Mercury to be seen? What is a transit of Mercury? 142. Where is the orbit of Venus, in respect to that of the Earth? What is the time of Venus' revolution around the Sun? How often does she turn on her axis?

proves that she has an atmosphere. Some of her mountains are several times more elevated than any on our globe, being from 10 to 22 miles high.

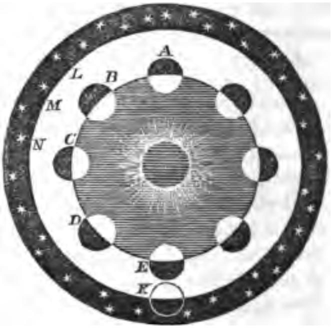
144. Venus sometimes makes a transit across the Sun's disc, in the same manner as Mercury, already described. The transits of Venus occur only at distant periods from each other. The last transit was in 1769, and the next will not happen until 1874. These transits have been observed by astronomers with the greatest care and accuracy, since it is by observations on them that the true distances of the Earth and planets from the Sun are determined.

145. *Motions and Phenomena of Venus.*—Sometimes Venus appears to recede from the Sun, and then approach him, and as her orbit is within that of the earth, her distance from us varies from 27,000,000 to 163,000,000 of miles. When nearest the earth she forms her *inferior* conjunction with the Sun, that is, she is between us and him, and hence being overpowered with his light, is invisible. When at the greatest distance from us, she forms her *superior* conjunction with that luminary, and for the same reason again becomes invisible to us.

These phenomena will be understood by the following explanations in connection with *Fig.* 257.

146. Let the Earth be supposed at K, then when Venus is in the position marked A, she is in a line with the Sun as seen from the Earth, and is then in her *superior* conjunction, being in the remotest part of her orbit. When in this position, the whole of her enlightened hemisphere is toward the Earth, but is invisible on account of the Sun's light. As she moves from A to B, being from west to east, which is called her *direct* motion, she begins to appear after sunset as the evening star. When

FIG. 257.



Phases of Venus.

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143. What is said of the height of the mountains in Venus? 144. On what account are the transits of Venus observed with great care? 145. What is the least and greatest distance of Venus from the Earth? When is she in her *inferior*, and when in her *superior* conjunction with the Sun? Why is she invisible in these two positions? 146. Describe by means of Fig. 257, the phases of Venus, from her superior to her inferior conjunction with the Sun.

at B, she appears among the stars at L, when she appears in a gibbous shape, nearly half her disc being luminous. When at C, she appears among the stars at M, nearly in the form of a half moon. At D, being at the point of her greatest elongation, she has the form of a half moon, and is seen among the stars at N. She now gradually becomes so overpowered by the Sun's rays as to be invisible to the naked eye, and when arrived at E, forms her inferior conjunction with the Sun, and her nearest approach to the Earth.

147. In this position, Venus is 36,000,000 miles nearer the Earth than when in her superior conjunction, and hence the great difference in her apparent size, and the luster with which she shines upon us. When near her superior conjunction, almost her entire disc is enlightened to us, and yet she appears like a faint star when compared with her luster when near her inferior conjunction, and when only her small crescent is turned toward us.

When Venus is in that part of her orbit which gives her the appearance of being west of the Sun, she rises before him, and is then called the *morning* star; and when she appears east of the Sun, she is behind him in her course, and is then called the *evening* star. These periods do not agree, either with the yearly revolution of the Earth, or of Venus, for she is alternately 290 days the morning star, and 290 the evening star. The reason of this is, that the Earth and Venus move round the Sun in the same direction, and hence her relative motion, in respect to the Earth, is much slower than her absolute motion in her orbit. If the Earth had no yearly motion, Venus would be the morning star one half of the year, and the evening star the other half.

THE EARTH.

148. The next planet in our system, nearest the Sun, is the Earth. Her diameter is nearly 8,000 miles. This planet revolves around him in 365 days, 5 hours, and 48 minutes; and at the distance of 95 millions of miles. She turns round her own axis once in 24 hours, making a day and a night. The Earth's revolution around the Sun is called her *annual* or *yearly* motion, because it is performed in a year; while the

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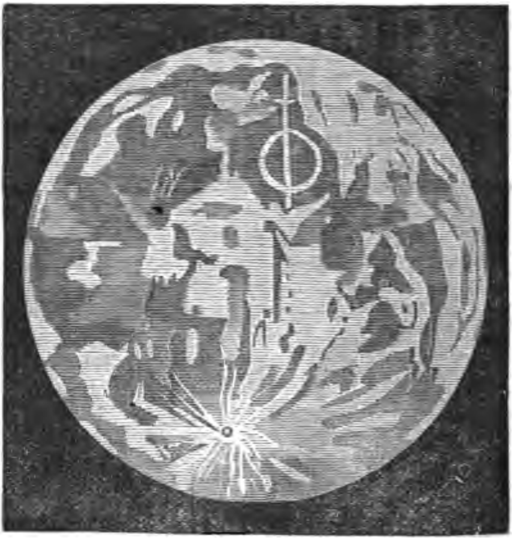
147. Why is the light of Venus to us so much less at some times than at others? How much nearer the earth is this planet at her inferior than at her superior conjunction? When is Venus the morning and when the evening star? How long is Venus the morning and how long the evening star? 148. How long does it take the Earth to revolve round the Sun? What is meant by the Earth's annual revolution, and what her diurnal revolution?

revolution around its own axis, is called the *diurnal* or daily motion, because it takes place every day. The earth's motion in her orbit is at the rate of 68,000 miles per hour. The figure of the Earth, with the phenomena connected with her motion, will be explained in another place.

THE MOON.

149. The Moon, next to the Sun, is, to us, the most brilliant and interesting of all the celestial bodies. Being the nearest to us of any of the heavenly orbs, and apparently designed for our use, she has been observed with great attention, and many of the phenomena which she presents, are therefore better understood and explained, than those of the other planets.

FIG. 258.



Full Moon.

While the Earth revolves round the sun in a year, it is attended by the Moon, which makes a revolution round the Earth once in 27 days, 7 hours, and 43 minues. The distance

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149. Why are the phenomena of the Moon better explained than those of the other planets? In what time is a revolution of the Moon about the Earth performed? What is the distance of the Moon from the Earth?

of the Moon from the Earth is 240,000 miles, and her diameter about 2,000 miles.

Her surface, when seen through a telescope, appears diversified with hills, mountains, valleys, rocks, and plains, presenting a most interesting and curious aspect: but the explanation of these phenomena are reserved for another section.

150. *Description of the Moon.*—The full Moon, seen through a telescope magnifying about 100 times, *Fig.* 258, is from Dick's "Celestial Scenery." The dark shades represent the level parts of the Moon's surface, and the lighter shades, those which are more elevated, some of them being mountains.

The bright spot, with a little round figure in the center, situated near the lower limb, and from which streaks, or streams of light, seem to proceed, is by some astronomers called *Tycho*, and by others *Mount Etna.* It consists of a large irregular cavity, surrounded by mountains, and these streaks of light are their highest parts, or ridges, which in their directions converge toward a center. This portion is the most variegated as well as elevated region of the lunar surface.

MARS.

151. The next planet in the solar system, is Mars, his orbit surrounding that of the Earth. The diameter of this planet is upward of 4,000 miles, being about half that of the Earth. The revolution of Mars, around the Sun is performed in nearly 687 days, or in somewhat less than two of our years, and he turns on his axis once in 24 hours and 40 minutes. His mean distance from the Sun is 144,000,000 of miles, so that he moves in his orbit at the rate of about 55,000 miles in an hour. The days and nights at this planet, and the different seasons of the year, bear a considerable resemblance to those of the Earth. The density of Mars is less than that of the Earth, being only three times that of water.

152. *Telescopic View of Mars.*—This planet, to the naked eye, reflects a yellowish, or dull red light, by which he may be distinguished from all the others. His telescopic appearance is quite peculiar, and often interesting, on account of the changes his face presents, being sometimes spotted, then striped, then clouded, and so on; and sometimes all these figures appear at the same time, presenting a great variety of aspects, some of

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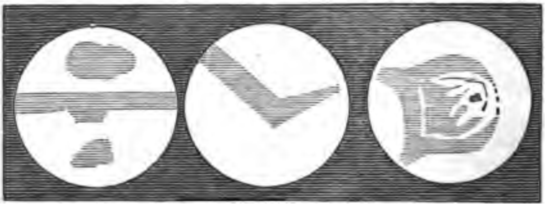
151. What is the diameter of Mars? How much longer is a year at Mars than our year? What is his rate of motion in his orbit? 152. What is his appearance through the telescope? How is it proved that Mars has an atmosphere of great density? Why does Mars sometimes appear to us larger than at others? How great is the Sun's heat at Mars?

which are represented by *Fig.* 259. It is difficult to account for these appearances, though they are attributed to dense vapor in the atmosphere of the planet.

FIG. 259.



Telescopic Phases of Mars.

Mars has an atmosphere of great density and extent, as is proved by the dim appearance of the fixed stars, when seen through it. When any of the stars are seen nearly in a line with this planet, they give a faint, obscure light, and the nearer they approach the line of his disc, the fainter is their light, until the star is entirely obscured from the sight.

This planet sometimes appears much larger to us than at others, and this is readily accounted for by his greater or less distance. At his nearest approach to the Earth, his distance is only 50 millions of miles, while his greatest distance is 240 millions of miles, making a difference in his distance of 190 millions of miles, or the diameter of the Earth's orbit.

The Sun's heat at this planet is less than half that which we enjoy.

To the inhabitants of Mars, our planet appears alternately as the morning and evening star, as Venus does to us.

JUPITER.

153. *Jupiter is* 89,000 *miles in diameter, and performs his annual revolution once in about* 11 *of our years, at the distance of* 490 *millions of miles from the Sun.* This is the largest planet in the solar system, being about 1,400 times larger than the Earth. His diurnal revolution is performed in nine hours and fifty-six minutes, giving his surface, at the equator, a motion of 28,000 miles per hour. This motion is about twenty times more rapid than that of our Earth at the equator.

Jupiter, next to Venus, is the most brilliant of the planets,

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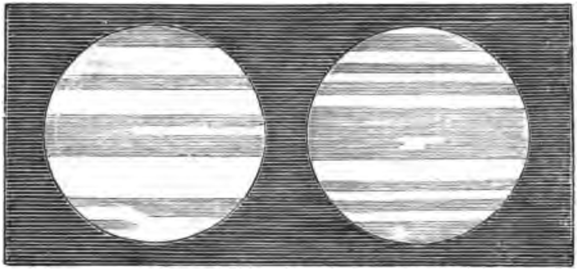
153. What is the diameter of Jupiter? What is his distance from the Sun? What is the period of Jupiter's diurnal revolution? What is the Sun's heat and light at Jupiter, when compared with that of the Earth? For what is Jupiter particularly distinguished? Is the appearance of Jupiter's belts always the same, or do they change? What is said of the cause of Jupiter's belted appearance?

though the light and heat of the Sun on him is nearly 25 times less than on the earth.

This planet is distinguished from all the others, by an appearance resembling bands, which extend across his disc. These are termed *belts*, and are variable, both in respect to number and appearance. Sometimes seven or eight are seen, several of which extend quite across his face, while others appear broken, or interrupted.

FIG. 260.



Belts of Jupiter.

These bands, or belts, when the planet is observed through a telescope, appear as represented in *Fig.* 260. This appearance is much the most common, the belts running quite across the face of the planet in parallel lines. Sometimes, however, his aspect is quite different from this, for in 1780, Dr. Herschel saw the whole disc of Jupiter covered with small curved lines, each of which appeared broken, or interrupted, the whole having a parallel direction across his disc, as in *Fig.* 261.

154. Jupiter has four satellites, or moons, two of which are sometimes seen with the naked eye. They move round, and attend him in his yearly revolution, as the Moon does our Earth. They complete their revolutions at different periods, the shortest of which is less than two days, and the longest seventeen days.

155. *Eclipses of Jupiter's Moons.*—These satellites often fall into the shadow of their primary, in consequence of which they are eclipsed, as seen from the Earth. The eclipses of Jupiter's moons have been observed with great care by astronomers, because they have been the means of determining the exact longitude of places, and the velocity with which light moves

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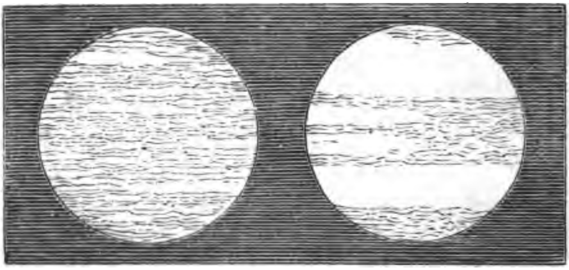
154. How many moons has Jupiter, and what are the periods of their revolutions? 155. What occasions the eclipses of Jupiter's moons? Of what uses are these eclipses to astronomers? How is the velocity of light ascertained by the eclipses of Jupiter's satellites?

FIG. 261.



Occasional Views of Jupiter.

through space. How longitude is determined by these eclipses, can not be explained or understood at this place, but the method by which they become the means of ascertaining the velocity of light, may be readily comprehended. An eclipse of one of these satellites appears, by calculation, to take place sixteen minutes sooner, when the Earth is in that part of her orbit nearest to Jupiter, than it does when the Earth is in that part of her orbit at the greatest distance from him. Hence, light is found to be sixteen minutes in crossing the Earth's orbit, and as the Sun is in the center of this orbit, or nearly so, it must take about eight minutes for the light to come from him to us. Light, therefore, passes at the velocity of 95 millions of miles, our distance from the Sun, in about eight minutes, which is nearly 200,000 miles in a second.

SATURN.

156. *The planet Saturn revolves round the Sun in a period of about* 30 *of our years, and at the distance from him of* 900 *millions of miles.* His diameter is 79,000 miles, making his bulk nearly nine hundred times greater than that of the Earth, but notwithstanding this vast size, he revolves on his axis once in about ten hours. Saturn, therefore, performs upward of 25,000 diurnal revolutions in one of his years, and hence his year consists of more than 25,000 days; a period of time equal to more than 10,000 of our days. On account of the remote distance of Saturn from the Sun, he receives only about a 90th part of the heat and light which we enjoy on the Earth. But

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156. What is the time of Saturn's periodic revolution round the Sun? What is his distance from the Sun? What his diameter? What is the period of his diurnal revolution? How many days make a year at Saturn? How many moons has Saturn?

to compensate, in some degree, for this vast distance from the Sun, Saturn has eight moons, which revolve round him at different distances, and at various periods, from 1 to 80 days.

157. *Rings of Saturn.*—Fig. 262 represents the several phases of Saturn as seen through a good telescope. No. 1, shows how the planet appeared in 1832, the plane of the ring being parallel to the line of vision, when nothing was perceptible, except the double line across his disc, as shown by the figure.

No. 2, shows the line of the rings across the center, terminated on each side by a thread of light.

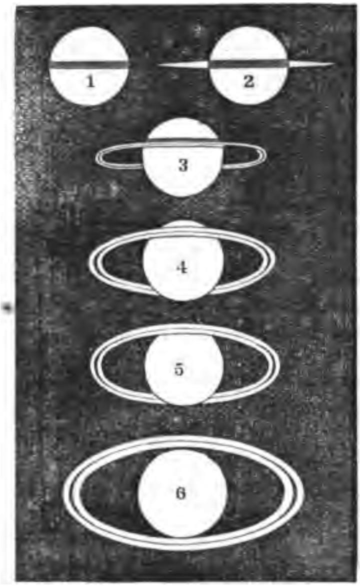
No. 3, shows the appearance of the rings and planet in 1834, a minute opening, between the rings, being apparent.

No. 4, shows the two rings a little wider apart as seen in 1835.

No. 5, shows the rings still wider apart.

No. 6, represents the rings as near a circle as they are ever seen, showing, also, the dark, thread-like space by which they are separated.

FIG. 262.



Saturn and his Rings.

These different phases of Saturn, to be seen distinctly, require a telescope which magnifies nearly 300 times.

In the last position, this wonderful planet was seen in 1840, after which it again passed through all the gradations above represented, appearing narrower every year until 1847, when

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157. How is Saturn particularly distinguished from all the other planets? What distance is there between the body of Saturn and his inner ring? What distance is there between his inner and outer ring? What is the circumference of the outer ring?

his appearance was again like No. I, and these changes are perpetually going on.

The external circumference of the outer ring is 630,000 miles. and its breadth from the outer to the inner circumference, 7,200 miles, or nearly the diameter of our Earth. The dark space, between the two rings, or the interval between the inner and the outer ring, is 2,800 miles.

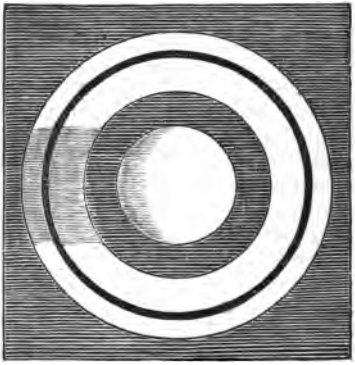
A third ring, interior to those heretofore known, was discovered in 1851, by Mr. Bond, of Cambridge, Mass.

This immense appendage revolves round the Sun with the planet,—performs daily revolutions with it and, according to Dr. Herschel, is a solid substance, equal in density to the body of the planet itself.

158. As this planet revolves around the Sun, one of its sides is illuminated during one half of the year, and the other side during the other half; so that, as Saturn's year is equal to thirty of our years, one of his sides will be enlightened and darkened, alternately, every fifteen years, as the poles of our Earth are alternately in the light and dark every year.

Fig. 263 represents Saturn as seen by an eye placed at right-angles to the plane of his ring. When seen from the Earth, his position is always oblique, as represented by *Fig.* 262.

FIG. 263.



Direct View of Saturn.

HERSCHEL.

159. In consequence of some inequalities in the motions of Jupiter and Saturn, in their orbits, several astronomers had suspected that there existed another planet beyond the orbit of Saturn, by whose attractive influence these irregularities were produced. This conjecture was confirmed by Dr. Herschel, in

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158. How long is one of Saturn's sides alternately in the light and dark? In what position is Saturn represented by Fig. 263? 159. What circumstance led to the discovery of Herschel?

1781, who in that year discovered the planet, which is now generally known by the name of its discoverer, though called by him *Georgium Sidus.* The orbit of Herschel is beyond that of Saturn, and at the distance of 1,800 millions of miles from the Sun. To the naked eye, this planet appears like a star of the sixth magnitude, being, with the exception of some of the comets and Neptune, the most remote body, so far as known in the solar system.

160. Herschel completes his revolution round the Sun in nearly 84 of our years, moving in his orbit at the rate of 15,000 miles in an hour. His diameter is 35,000 miles, so that his bulk is about eighty times that of the Earth. The light and heat of the Sun at Herschel, is about 360 times less than it is at the Earth, and yet it has been found, by calculation, that this light is equal to 248 of our full Moons; a striking proof of the inconceivable quantity of light emitted by the Sun.

This planet has six satellites, which revolve round him at various distances, and in different times. The periods of some of these have been ascertained, while those of the others remain unknown.

NEPTUNE.

161. The discovery of this planet is a signal instance of the power of mathematical calculations, applied to the motions of the celestial bodies.

Astronomers, for more than half a century, had observed from various parts of the world, certain secular perturbations in several of the most remote members of the solar system, especially in Saturn and Herschel.

These irregular motions, due to the law of attraction, could not be explained by the influence of any known body, circulating around the Sun, and hence the inference that there existed in that region, another planet not yet seen by mortal eyes.

162. Two young astronomers, Adams, an Englishman, and Leverrier, a citizen of France, unknown to each other, pursuing this suggestion, both demonstrated, not only the existence of this undiscovered body, but showed within a few degrees the point in the heavens where it would be found, and where in truth the discovery was made. Dr. Galle, of Berlin, sweeping

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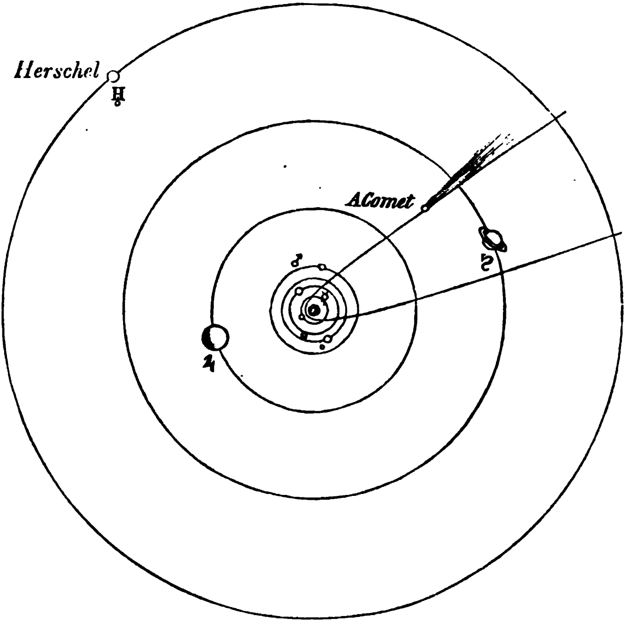
159. In what year, and by whom was Herschel discovered? What is the distance of Herschel from the Sun? 160. In what period is his revolution round the Sun performed? What is the diameter of Herschel? What is the quantity of light and heat at Herschel, when compared with that of the Earth? 162. By whom, and in what manner was Neptune discovered?

the heavens with his telescope, according to the directions of these demonstrators, first saw the planet now called Neptune, on the 26th of September, 1846. Still Leverrier and Adams, by the common consent of astronomers and the scientific world, must have the honor of this discovery, "so that the discovery of Neptune has happily crowned two heads with laurels."

FIG. 264.



Relative Distance of the Planets.

163. This planet was first called *Leverrier*, but it seems that astronomers have long since determined that new ones shall not receive the names of their discoverers, but of some heathen divinity, and hence Herschel, the name of the discoverer, has been changed to Uranus, and Leverrier into Neptune.

164. *Distance of Neptune.*—It is stated in the table of the planets, that the distance of Neptune from the Sun, is 2,850 millions of millions of miles. On this subject, a curious calcu-

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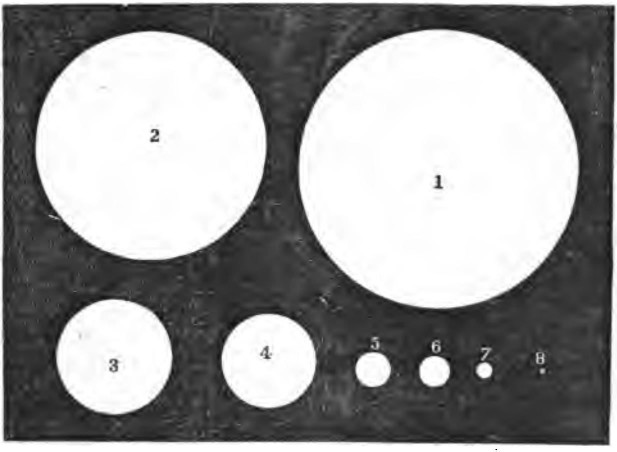
163. What is said about calling new planets after their discoverers?

lator says, "Had Adam and Eve started on a railway, to go from Neptune to the Sun, at the rate of fifty miles an hour, they would not yet have arrived there, for this planet, at the above rate, is more than 6000 years from the center of our system." And yet this orb was discovered by the science of man.

RELATIVE SITUATIONS OF THE PLANETS.—Having now given a short account of each planet composing the solar system, the relative situations of their several orbits, with the exception of those of the Asteroids and Neptune, are shown by *Fig.* 264.

In this figure, the orbits are marked by the signs of each planet, of which the first, or that nearest the Sun, is Mercury, the next Venus, the third the Earth, the fourth Mars; then come those of the Asteroids, then Jupiter, then Saturn, and lastly Herschel.

FIG. 265.



Relative Sizes of the Planets.

No. 1. JUPITER. No. 2, SATURN, WITHOUT HIS RINGS. No. 3, HERSCHEL. No. 4, NEPTUNE. No. 5, EARTH. No. 6, VENUS. No. 7, MARS. No. 8, MERCURY.

165. COMPARATIVE DIMENSIONS OF THE PLANETS.—The comparative dimensions of the planets are delineated at *Fig.* 265.

MOTIONS OF THE PLANETS.

166. It is said, that when Sir Isaac Newton was near dem-

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164. How long would it take to go from our system to Neptune, at the rate of fifty miles an hour?

onstrating the great truth, that gravity is the cause which keeps the heavenly bodies in their orbits, he became so agitated with the thoughts of the magnitude and consequences of this discovery, as to be unable to proceed with his demonstrations, and desired a friend to finish what the intensity of his feelings would not allow him to complete.

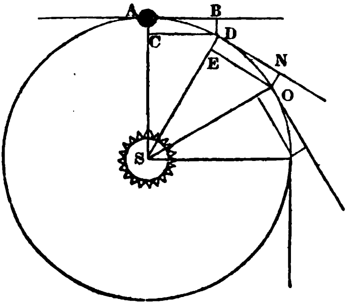
We have seen, in a former part of this work, (183.) that all undisturbed motion is straight forward, and that a body projected into open space, would continue perpetually, to move in a right line, unless retarded or drawn out of this course by some external cause.

To account for the motions of the planets in their orbits, we will suppose that the Earth, at the time of its creation, was thrown by the hand of the Creator into open space, the Sun having been before created and fixed in his present place.

167. *Circular Motion of the Planets.*—Under *Compound Motion*, (190,) it has been shown, that when a body is acted on by two forces perpendicular to each other, its motion will be in a diagonal between the direction of the two forces.

168. Now let A, *Fig.* 266, represent the Earth, and S, the Sun; and suppose the Earth to be moving forward, in the line from A to B, and to have arrived at A, with a velocity sufficient, in a given time, and without disturbance, to have carried it to B. But at the point, A, the Sun, S, acts upon the Earth with his attractive power, and with a force which would draw it to C, in the same space of time that it would otherwise have gone to B. Then the Earth, instead of passing to B, in a straight line, would be drawn down to D, the diagonal of the parallelogram, A B D C, but it is curved from A to D, in consequence of the continued force of the Sun's attraction, which produces a constant deviation from a right line.

FIG. 266.



Circular Motion of the Planets.

When the Earth arrives at D, still retaining its projectile or

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167. Suppose a body to be acted upon by two forces perpendicular to each other, in what direction will it move? Why does the Earth, Fig. 266, move in a curved line? Explain Fig. 266, and show how the two forces act to produce a circular line of motion?

centrifugal force, its line of direction would be toward N; but, while it would pass along to N without disturbance, the attracting force of the Sun is again sufficient to bring it to E, in a straight line, so that, in obedience to the two impulses, it again describes the curve to O.

It must be remembered, in order to account for the circular motions of the planets, that the attractive force of the Sun is not exerted at once, or by a single impulse, as is the case with the cross forces, producing a straight line, but that this force is imparted by degrees, and is constant. It, therefore, acts equally on the Earth, in all parts of the course from A to D, and from D to O, *Fig.* 266. From O, the Earth having the same impulses as before, it moves in the same curved or circular direction, and thus its motion is continued perpetually.

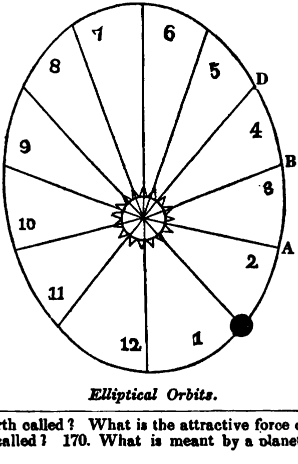
169. The tendency of the Earth to move forward in a straight line, is called the *centrifugal force*, and the attraction of the Sun, by which it is drawn downward, or toward a center, is called its *centripetal force*, and it is by these two forces that the planets are made to perform their constant revolutions around the Sun. (197.)

170. *Planets Pass Equal Areas in Equal Times.*—It is an interesting circumstance, respecting the motions of the planets, that if the contents of their eliptical orbits be divided into unequal triangles, the acute angles of which center at the Sun, with the line of the orbit for their bases, the center of the planet will pass through each of these bases in equal times.

This will be understood by *Fig.* 267, the elliptical circle being supposed to be the Earth's orbit, with the Sun in one of the foci.

Now, the spaces, 1, 2, 3 &c., though of different shapes are of the same dimensions, or contain the same quantity of surface. The Earth, we have already seen, in its journey round the Sun, describes

FIG. 267.



Elliptical Orbits.

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169. What is the projectile force of the Earth called? What is the attractive force of the Sun which draws the Earth toward him called? 170. What is meant by a planet's passing through equal spaces in equal times?

an ellipse, and moves more rapidly in one part of its orbit than in another. But, what ever may be its actual velocity, its comparative motion is through equal areas in equal times. Thus, its center passes from A to B, and from B to D, in the same period of time, and so of all the other divisions marked in the figure. If the figure, therefore, be considered the plane of the Earth's orbit, divided into 12 equal areas, answering to the 12 months of the year, the Earth will pass through the same areas in every month, but the spaces through which it passes will be increased, during every month, for one half the year, and diminished, during every month, for the other half.

171. *Why the Planets do not Fall to the Sun.*—The reason why the planets, when they approach near the Sun, do not fall to him, in consequence of his increased attraction, and why they do not fly off into open space, when they recede to the greatest distance from him, may be thus explained.

Taking the Earth as an example, we have shown that when in the part of her orbit nearest the Sun, her velocity is greatly increased by his attraction, and that, consequently, the Earth's centrifugal force is increased in proportion.

172. Now, the velocity of the earth increases in an inverse proportion, as its distance from the Sun diminishes, and, in proportion to the increase of velocity, is its centrifugal force increased; so that, in any other part of its orbit, except when nearest the Sun, this increase of velocity would carry the Earth away from its center of attraction. But, this increase of the Earth's velocity is caused by its near approach to the Sun, and, consequently, the Sun's attraction is increased as well as the Earth's velocity. In other terms, when the centrifugal force is increased, the centripetal force is increased in proportion, and thus, while the centrifugal force prevents the Earth from falling to the Sun, the centripetal force prevents it from moving off in a straight line.

THE EARTH.

173. *Proofs of the Earth's Diurnal Revolution.*—It is almost universally believed, at the present day, that the apparent daily motion of the heavenly bodies from east to west is caused by the real motion of the Earth from west to east; and, yet, there

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171. How is it shown that, if the motion of a revolving body is increased, its projectile force is also increased? 172. By what force is the Earth's velocity increased as it approaches the Sun? When the Earth is nearest the Sun, why does it not fall to him? When the Earth's centrifugal force is greatest, what prevents its flying from the Sun? 173. What are the most obvious and convincing proofs that the Earth revolves on its axis?

are comparatively few who have examined the evidence on which this belief is founded. For this reason, we will here state the most obvious, and, to a common observer, the most convincing proofs of the Earth's revolution. These are, first, the inconceivable velocity of the heavenly bodies, and particularly the fixed stars, around the Earth, if she stands still. Second, the fact that all astronomers of the present age agree that every phenomenon which the heavens present can be best accounted for, by supposing the Earth to revolve. Third, the analogy to be drawn from many of the other planets, which are known to revolve on their axes; and, fourth, the different lengths of days and nights at the different planets; for, did the Sun revolve about the solar system, the days and nights at many of the planets must be of similar lengths.

174. The distance of the Sun from the Earth being 95 millions of miles, the diameter of the Earth's orbit is twice its distance from the Sun, and, therefore, 190,000,000 of miles. Now, the diameter of the Earth's orbit, when seen from the nearest fixed star, is a mere point, and were the orbit a solid mass of dark matter, it could not be seen, with such eyes as ours, from such a distance. This is known by the fact, that these stars appear no larger to us, even when our sight is assisted by the best telescopes, when the Earth is in that part of her orbit nearest them, than when at the greatest distance, or in the opposite part of her orbit. The approach, therefore, of 190 millions of miles toward the fixed stars, is so small a part of their whole distance from us, that it makes no perceptible difference in their appearance.

175. Now, if the Earth does not turn on her axis once in 24 hours, these fixed stars must revolve around the Earth at this amazing distance once in 24 hours. If the Sun passes around the Earth in 24 hours, he must travel at the rate of nearly 400,000 miles in a minute; but, the fixed stars are, at least, 400,000 times as far beyond the Sun as the Sun is from us; and, therefore, if they revolve around the Earth, must go at the rate of 400,000 times 400,000 miles, that is, at the rate of 160,000,000,000, or 160 billions of miles in a minute; a velocity of which we can have no more conception than of infinity or eternity.

176. In respect to the analogy to be drawn from the known revolutions of the other planets, and the different lengths of

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174. Were the Earth's orbit a solid mass, could it be seen by us at the distance of the fixed stars? **175.** Suppose the Earth stood still, how fast must the Sun move to go round it in 24 hours? At what rate must the fixed stars move to go round it in 24 hours?

days and nights among them, it is sufficient to state, that to the inhabitants of Jupiter, the heavens appear to make a revolution in about 10 hours, while, to those of Venus, they appear to revolve once in 23 hours, and, to the inhabitants of the other planets a similar difference seems to take place, depending on the periods of their diurnal revolutions.

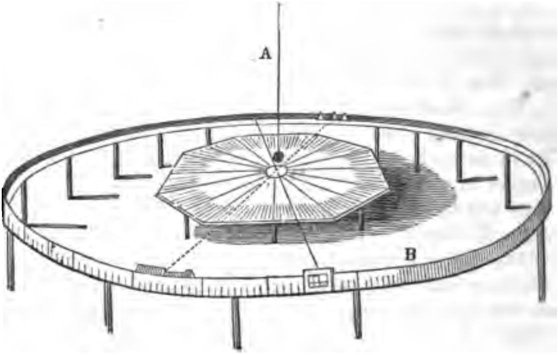
177. Now, there is no more reason to suppose that the heavens revolve round us than there is to suppose that they revolve around any of the other planets, since the same apparent revolution is common to them all; and, as we know that the other planets, at least many of them, turn on their axes, and, as all the phenomena presented by the Earth can be accounted for by such a revolution, it is folly to conclude otherwise.

ROTATION OF THE EARTH MADE VISIBLE.

178. Although astronomers and others who have enquired into the subject, have all the proof they want that the earth turns on her axis once in 24 hours, yet, it is but lately that any ocular proof of this great philosophical fact has been discovered and offered to the public.

The following diagram, *Fig.* 268, and the explanation, will show how the rotation in question may be demonstrated. The experiment was first made at the Pantheon in Paris, in 1849.

FIG. 268.



Rotation of the Earth made Visible.

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176. Is there any more reason to believe that the Sun revolves around the Earth than round any of the other planets? How can all the phenomena of the heavens be accounted for if the planets do not revolve? 177. If the heavens appear to revolve every 10 hours at Jupiter, and every 24 hours at the Earth, how can this difference be accounted for, if they revolve at all?

To the dome of the Pantheon, say 250 feet from the floor, was attached a fine wire, A, which suspended a metallic ball, vibrating like a pendulum, within an inch or two of the center of the circular table, B. This table, 12 or 15 feet in diameter, was divided into 360 degrees, in order to show the rates of circular motion which the earth undergoes.

179. Now, it can be shown by this apparatus that, supposing the Earth to have the diurnal revolution imputed to her around her axis, and, by which the phenomena of day and night are explained, then, by the same law, the table with the degrees marked around its circumference will show, when compared with the pendulum, that the table revolves with the Earth; for, the pendulum, being suspended on a point, does not revolve. Therefore, if, on making the ball vibrate, (a lead-pencil leaving a mark across the table), the direction of the line of vibration differs at different hours of the day, then it is plain that the table has moved; for, the center of the vibratory motion being a fixed point, cannot revolve, and the plane, therefore, through which its vibration passes, will be exactly the same during the 24 hours.

180. If, therefore, the ball of the pendulum furnished with a pencil, and paper be spread on the table, the lines left by it on the paper would show, from hour to hour, the progressive motion of the Earth, and would form angles with each other of 15 degrees, or, the twenty-fourth part of the great circle of the Earth for each hour. (See Longitude.)

181. This, indeed, it is said, was actually visible to the crowds who flocked to the Pantheon to witness this wonderful experiment; for, however credulous many came, they saw with their own eyes the changes which took place between the ball and the table.

HORIZON.

182. The horizon is distinguished into the *sensible* and *rational.* The sensible horizon is that portion of the surface of the Earth which bounds our vision, or the circle around us, where the sky seems to meet the Earth. When the Sun rises, he appears above the sensible horizon; and, when he sets, he sinks below it. The rational horizon is an imaginary line, passing through the center of the Earth, and dividing it into two equal parts.

183. INCLINATION OF THE EARTH'S AXIS.—The inclination of the Earth's axis to the axis of its orbit never varies, but

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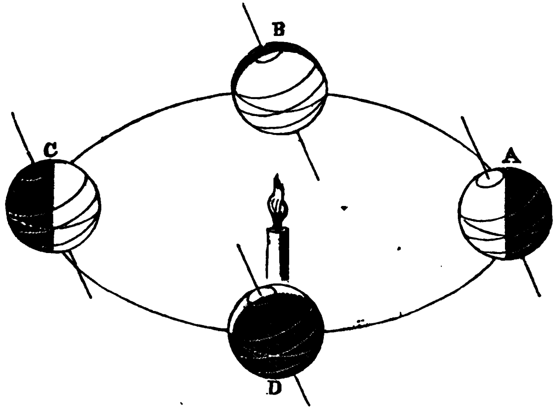
182 How is the sensible horizon distinguished from the rational?

FIG. 269.



Inclination of the Earth's Axis.

always makes an angle with it of 23½ degrees, as it moves round the Sun. The axis of the Earth is, therefore, always parallel with itself. That is, if a line be drawn through the center of the Earth, in the direction of its axis, and extended north and south, beyond the Earth's diameter, the line so produced, will always be parallel to the same line, or any number of lines, so drawn, when the Earth is in different parts of its orbit.

Suppose a rod to be fixed into the flat surface of a table, and so inclined as to make an angle with a perpendicular from the table of 23½ degrees. Let this rod represent the axis of the Earth, and the surface of the table the ecliptic. Now, place on the table a lamp, and round the lamp hold a wire circle, three or four feet in diameter, so that it shall be parallel with the plane of the table, and as high above it as the flame of the lamp. Having prepared a small terrestrial globe, by passing a wire through it for an axis, and letting it project a few inches each way for the poles, take hold of the north pole and carry it round the circle, with the poles constantly parallel to the rod rising above the table. The rod being inclined 23½ degrees from a perpendicular, the poles and axis will be inclined in the same degree, and thus the axis of the Earth will be inclined to

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183. Are the orbits of the other planets parallel to the Earth's orbit, or inclined to it? What is meant by the Earth's axis being parallel to itself?

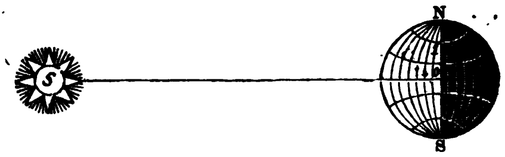
that of the ecliptic everywhere in the same degree, and, lines, drawn in the direction of the Earth's axis, will be parallel to each other in any part of its orbit.

184. This will be understood by *Fig.* 269, where it will be seen, that the poles of the Earth, in the several positions of A B C and D, being equally inclined, are parallel to each other. Supposing the lamp to represent the Sun, and the wire circle the Earth's orbit, the actual position of the Earth, during its annual revolution around the Sun, will be comprehended, and if the globe be turned on its axis, while passing round the lamp, the diurnal, or daily revolutions of the Earth will also be represented.

DAY AND NIGHT.

185. *Were the direction of the Earth's axis perpendicular to the plane of its orbit, the days and nights would be of equal length all the year, for then just one half of the Earth, from pole to pole, would be enlightened, and at the same time the other half would be in darkness.*

FIG. 270.



Day and Night.

Suppose the line S, *o*, *Fig.* 270, from the Sun to the Earth, to be the plane of the Earth's orbit, and that N S is the axis of the Earth perpendicular to it, then it is obvious, that exactly the same points on the Earth would constantly pass through the alternate vicissitudes of day and night; for all who live on the meridian line between N and S, which line crosses the equator at *o*, would see the Sun at the same time, and consequently, as the Earth revolves, would pass into the dark hemisphere at the same time. Hence, in all parts of the globe, the days and nights would be of equal length, at any given place.

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184. How does it appear by Fig. 269, that the axis of the Earth is parallel to itself, in all parts of its orbit? 185. How are the annual and diurnal revolutions of the Earth illustrated by Fig. 270? Explain by Fig. 270, why the days and nights would every where be equal, were the axis of the Earth perpendicular to the plane of his orbit.

186. Now it is the inclination of the Earth's axis, as above described, which causes the length of the days and nights to differ at the same place at different seasons of the year; for on reviewing the position of the globe at A, *Fig.* 269, it will be observed that the line formed by the enlightened and dark hemispheres, does not coincide with the line of the axis and pole, as in *Fig.* 270, but that the line formed by the darkness and the light, extends obliquely across the line of the Earth's axis, so that the north pole is in the light while the south is in the dark. In the position of A, therefore, an observer at the north pole would see the sun constantly, while another at the south pole would not see it at all. Hence, those living in the north temperate zone, at the season of the year when the Earth is at A, or in the Summer, would have long days and short nights, in proportion as they approached the polar circle; while those who live in the south temperate zone, at the same time, and when it would be Winter there, would have long nights and short days in the same proportion.

SEASONS OF THE YEAR.

187. *The vicissitudes of the seasons are caused by the annual revolution of the Earth round the Sun, together with the inclination of its axis to the plane of its orbit.*

It has already been explained, that the ecliptic is the plane of the Earth's orbit, and is supposed to be placed on a level with the Earth's horizon, and hence, that this plane is considered the standard, by which the inclination of the lines crossing the Earth, and the obliquity of the orbits of the other planets, are to be estimated.

188. *The Solstices.*—The solstices are the points where the ecliptic and the equator are at the greatest distance from each other. The Earth, in its yearly revolution, passes through each of these points. One is called the *Summer*, and the other the *Winter* solstice. The Sun is said to enter the Summer solstice on the 21st of June; and at this time, in our hemisphere, the days are longest and the nights shortest. On the 21st of December, he enters his Winter solstice, when the length of the days and nights are reversed from what they were in June before, the days being shortest, and the nights longest.

Having learned these explanations, the student will be able

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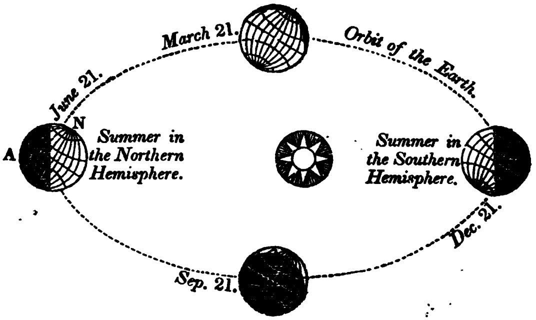
186. What is the cause of the unequal lengths of the days and nights in different parts of the world? 187. What are the causes which produce the seasons of the year? 188. What are the solstices? When the Sun enters the Summer solstice, what is said of the length of the days and nights? When does the Sun enter the Winter solstice, and what is the proportion between the length of the days and nights?

to understand in what order the seasons succeed each other, and the reason why such changes are the effect of the Earth's revolution.

REVOLUTIONS OF THE EARTH.

189. Suppose the Earth, *Fig.* 271, to be in her Summer solstice, which takes place on the 21st of June. At this period she will be at A, having her north pole, N, so inclined toward the Sun, that the whole arctic circle will be illuminated, and consequently the Sun's rays will extend 23½ degrees, the breadth of the polar circle, beyond the north pole. The diurnal revolution, therefore, when the Earth is at A, causes no succession of day and night at the pole, since the whole frigid zone is within the reach of his rays. The people who live within the arctic circle will, consequently, at this time, enjoy perpetual day.

FIG. 271.


March 21.
Orbit of the Earth.
June 21.
N
A
Summer in the Northern Hemisphere.
Summer in the Southern Hemisphere.
Dec. 21.
Sep. 21.

Seasons of the Year.

190. During this period, just the same proportion of the Earth that is enlightened in the northern hemisphere, will be in total darkness in the opposite region of the southern hemisphere; so that while the people of the north are blessed with perpetual day, those of the south are groping in perpetual night. Those who live near the arctic circle in the north temperate zone, will, during the Summer, come, for a few hours, within the regions

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189. At what season of the year is the whole arctic circle illuminated? **190.** At what season is the whole antarctic circle in the dark? While the people near the north pole enjoy perpetual day, what is the situation of those near the south pole?

of night, by the Earth s diurnal revolution; and the greater the distance from the circle, the longer will be their nights, and the shorter their days.

191. Hence, at this season, the days will be longer than the nights every where between the equator and the arctic circle. At the equator, the days and nights will be equal, and between the equator and the south polar circle, the nights will be longer than the days, in the same proportion as the days are longer than the nights, from the equator to the arctic circle.

192. *The Sun always Shines on* 180 *Degrees of the Earth.*—It will be observed by a careful perusal of the above explanation of the seasons, and a close inspection of the figure by which it is illustrated, that the Sun constantly shines on a portion of the Earth equal to 90 degrees north, and 90 degrees south, from his place in the heavens, and consequently, that he always enlightens 180 degrees, or one half of the Earth. If, therefore, the axis of the Earth were perpendicular to the plane of its orbit, the days and nights would every where be equal, for as the Earth performs its diurnal revolutions, there would be 12 hours day, and 12 hours night. But since the inclination of its axis is 23½ degrees, the light of the Sun is thrown 23½ degrees further in that direction, when the north pole is turned toward the Sun, than it would, had the Earth's axis no inclination. Now, as the Sun's light reaches only 90 degrees north or south of his place in the heavens, so when the arctic circle is enlightened, the antarctic circle must be in the dark; for if the light reaches 23½ degrees beyond the north pole, it must fall 23½ degrees short of the south pole.

193. As the Earth travels round the Sun, in his yearly circuit, this inclination of the poles is alternately toward and from him. During our Winter, the north polar region is thrown beyond the rays of the Sun, while a corresponding portion around the south pole enjoys the Sun's light. And thus, at the poles, there are alternately six months of darkness and Winter, and six months of sunshine and Summer.

194. While we, in the northern hemisphere, are chilled by the cold blasts of Winter, the inhabitants of the southern hemisphere are enjoying all the delights of Summer; and while we are scorched by the rays of a vertical Sun in June and

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191. At what season will the days be longer than the nights every where between the equator and the arctic circle? 192. How many degrees does the Sun's light reach, north and south of him, on the Earth? 193. During our Winter, is the north pole turned to or from the Sun? At the poles, how many days and nights are there in the year? 194. When it is Winter in the northern hemisphere, what is the season in the southern hemisphere?

July, our southern neighbors are shivering with the rigors of mid-Winter.

195. At the equator, no such changes take place. The rays of the Sun, as the Earth passes round him, are vertical twice a year at every place between the tropics. Hence, at the equator, there are two Summers and no Winter, and as the Sun there constantly shines on the same half of the Earth in succession, the days and nights are always equal, there being 12 hours of light and 12 of darkness.

196. Velocity of the Earth.—The motion of the Earth round the Sun, is at the rate of 68,000 miles in an hour, while its motion on its own axis, at the equator, is at the rate of about 1,042 miles in the hour. The equator being that part of the Earth most distant from its axis, the motion there is more rapid than toward the poles, in proportion to its greater distance from the axis of motion.

197. The method of ascertaining the velocity of the Earth's motion, both in its orbit and round its axis, is simple and easily understood; for by knowing the diameter of the Earth's orbit, its circumference is readily found, and as we know how long it takes the Earth to perform her yearly circuit, we have only to calculate what part of her journey she goes through in an hour. By the same principle, the hourly rotation of the Earth is as readily ascertained.

198. We are insensible to these motions, because not only the Earth, but the atmosphere, and all terrestrial things, partake of the same motion, and there is no change in the relation of objects in consequence of it.

CAUSES OF THE HEAT AND COLD OF THE SEASONS.

199. We have seen that the Earth revolves round the Sun in an elliptical orbit, of which the Sun is one of the foci, and consequently that the Earth is nearer him, in one part of her orbit than in another. From the great difference we experience between the heat of Summer and that of Winter, we should be led to suppose that the Earth must be much nearer the Sun in the hot season than in the cold. But when we come to inquire into this subject, and to ascertain the distance of the Sun at different seasons of the year, we find that the great source of heat

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195. What are the seasons at the equator? **196.** At what rate does the Earth move around the Sun? How fast does it move around its axis at the equator? **197.** How is the velocity of the Earth ascertained? **198.** Why are we insensible of the Earth's motion? **199.** At what season of the year is the Sun at the greatest, and at what season the least distance from the Earth?

and light is nearest us during the cold of Winter, and at the greatest distance during the heat of Summer.

200. *Angular Distance of the Sun.*—If, for instance, his apparent diameter be taken in March, and then again in July, it will be found to have diminished, which diminution is only to be accounted for, by supposing that he is at a greater distance from the observer in July than in March. From July, his angular diameter gradually increases, till January, when it again diminishes, and continues to diminish, until July. By many observations, it is found, that the greatest apparent diameter of the Sun, and therefore his least distance from us, is in January, and his least diameter, and therefore his greatest distance is in July.

201. The actual difference is about three millions of miles, the Sun being that distance further from the Earth in July than in January. This, however, is only about one-sixtieth of his mean distance from us, and the difference we should experience in his heat, in consequence of this difference of distance, will therefore be very small. Perhaps the effect of his proximity to the Earth may diminish, in some small degree, the severity of Winter.

202. *Temperature of Summer.*—The heat of Summer, and the cold of Winter, must, therefore, arise from the difference in the meridian altitude of the Sun, and in the time of his continuance above the horizon. In Summer, the solar rays fall on the Earth in nearly a perpendicular direction, and his powerful heat is then constantly accumulated by the long days and short nights of the season.

203. *Temperature of Winter.*—In Winter, on the contrary, the solar rays fall so obliquely on the Earth, as to produce little warmth, and the small effect they do produce during the short days of that season, is almost entirely destroyed by the long nights which succeed. The difference between the effects of perpendicular and oblique rays, seems to depend, in a great measure, on the different extent of surface over which they are spread.

204. When the rays of the Sun are made to pass through a convex lense, the heat is increased, because the number of rays which naturally cover a large surface, are then made to cover a smaller one, so that the power of the glass depends on the num-

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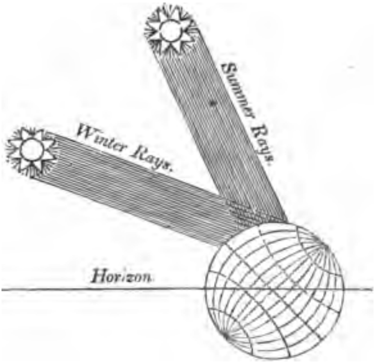
200. When does the Sun appear under the greatest apparent diameter, and when under the least? 201. How much further is the Sun from us in July than in January? What effect does this difference produce on the Earth? 202. How is the heat of Summer, and the cold of Winter, accounted for? 203. Why do the perpendicular rays of Summer produce greater effects than the oblique rays of Winter? 204. How is this illustrated by the convex and concave lenses?

ber of rays thus brought to a focus. If, on the contrary, the rays of the Sun are suffered to pass through a concave lense, their natural heating power is diminished, because they are dispersed, or spread over a wider surface than before.

FIG. 272.



Summer and Winter Rays.

205. *Summer and Winter Rays.*—Now to apply these different effects to the Summer and Winter rays of the Sun, let us suppose that the rays falling perpendicularly on a given extent of surface, impart to it a certain degree of heat, then, it is obvious that, if the same number of rays be spread over twice that extent of surface, their heating power would be diminished in proportion, and that only half the heat would be imparted. This is the effect produced by the Sun's rays in the Winter. They fall so obliquely on the Earth, as to occupy nearly double the space that the same number of rays do in the Summer.

This is illustrated by *Fig.* 272, where the number of rays, both in Winter and Summer, are supposed to be the same. But, it will be observed that the Winter rays, owing to their oblique direction, are spread over nearly twice as much surface as those of Summer.

206. It may, however, be remarked, that the hottest season is not usually at the exact time of the year when the Sun is most vertical and the days the longest, as is the case toward the end of June, but some time afterward, as in July and August.

207. To account for this, it must be remembered that, when the Sun is nearly vertical, the Earth accumulates more heat by day than it gives out at night; and, that this accumulation continues to increase after the days begin to shorten; and, consequently, the greatest elevation of temperature is some time after the longest days. For the same reason, the thermometer gen-

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205. How is the actual difference of the Summer and Winter rays shown? 206. Why is not the hottest season of the year at the period when the days are longest, and the Sun most vertical? 207. How is this accounted for?

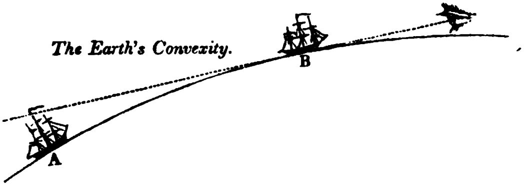
erally indicates the greatest degree of heat at two or three o'clock on each day, and not at twelve o'clock, when the Sun's rays are most powerful.

FIGURE OF THE EARTH.

208. Astronomers have proved that all the planets, together with their satellites, have the shape of the sphere or globe, and hence, by analogy, there was every reason to suppose that the Earth would be found of the same shape; and, several phenomena tend to prove, beyond all doubt, that this is its form. The figure of the Earth is not, however, exactly that of a globe, or ball, because its diameter is about 34 miles less from pole to pole than it is at the equator. But, that its general figure is that of a sphere or ball, is proved by many circumstances.

209. When one is at sea, or standing on the sea-shore, the first part of a ship seen at a distance, is its mast. As the vessel advances, the mast rises higher and higher above the horizon, and, finally, the hull and whole ship become visible. Now, were the Earth's surface an exact plane, no such appearance would take place; for, we should then see the hull long before the mast or rigging, because it is much the largest object.

FIG. 273.



Spheroidal Form of the Earth.

It will be plain, by *Fig.* 273, that, were the ship, A, elevated so that the hull should be on a horizontal line with the eye, the whole ship would be visible, instead of the topmast, there being no reason, except the convexity of the Earth, why the whole ship should not be visible at A, as well as at B.

210. It is a well known fact, also, that navigators have set out from a particular port, and, by sailing continually westward, have passed around the Earth, and again reached the port from

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208. What is the general figure of the Earth? How much less is the diameter of the Earth at the poles than at the equator? 209. How is the convexity of the Earth proved by the approach of a ship at sea? Explain Fig. 273. 210 What other proofs of the globular shape of the Earth are mentioned?

which they sailed. This could never happen, were the Earth an extended plain, since then the longer the navigator sailed in one direction, the further he would be from home.

Another proof of the spheroidal form of the Earth, is the figure of its shadow on the Moon, during eclipses, which shadow is always bounded by a circular line.

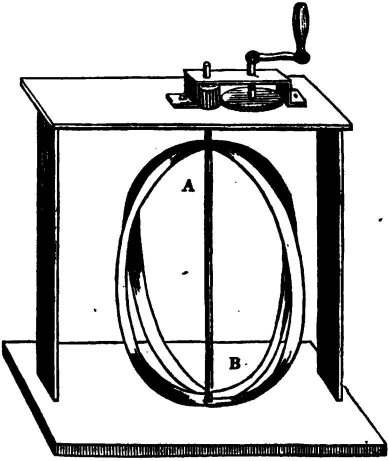
These circumstances prove, beyond all doubt, that the form of the Earth is globular, but that it is not an exact sphere; and, that it is depressed or flattened at the poles, is shown by the difference in the lengths of pendulums vibrating seconds at the poles, and at the equator.

211. *Compression at the Poles.*—The compression of the Earth at the poles, and the consequent accumulation of matter at the equator, is considered the effect of its diurnal revolution, while it was in a soft or plastic state. If a ball of soft clay or putty be made to revolve rapidly, by means of a stick passing through its center, as an axis, it will swell out in the middle, or equator, and be depressed at the poles, assuming the precise figure of the Earth.

212. *Centrifugal Force.*—The effects of centrifugal force are very satisfactorily illustrated in the following manner:

Two hoops of thin iron are placed upon an axis, which passes through their poles, as shown by *Fig.* 274. The two poles of each hoop cross each other at right-angles, and are fastened together, and to the axis at the bottom. At the upper end they slide up and down on the axis, which is turned rapidly by wheel-work as represented. These hoops, before the motion begins, have an oval form; but, when turned rapidly, the

FIG. 274.



Depression of the Poles.

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211. How is the form of the Earth illustrated by experiment? Explain the reason why a plastic ball will swell at the equator, when made to revolve. 212. Explain Fig. 274, and show how it illustrates the form of the earth

centrifugal force occasions them to expand, or swell at the equator, while they are depressed at the poles, the two polar regions becoming no more distant than A and B.

213. *Weight at the Poles.*—The weight of a body at the poles is found to be greater than at the equator, not only because the poles are nearer the center of the Earth than the equator, but because the centrifugal force there tends to lessen its gravity. The wheels of machines, which revolve with the greatest rapidity, are made in the strongest manner; otherwise, they will fly in pieces, the centrifugal force not only overcoming the gravity, but the cohesion of their parts.

214. It has been found, by calculation, that, if the Earth turned over once in 84 minutes and 43 seconds, the centrifugal force at the equator would be equal to the power of gravity there, and that bodies would entirely lose their weight. If the Earth revolved more rapidly than this, all the buildings, rocks, mountains, and men, at the equator, would not only lose their weight, but would fly away, and leave the Earth, as the water does from a revolving grindstone.

SOLAR AND SIDERIAL TIME.

215. The stars appear to go round the Earth in 23 hours, 56 minutes, and four seconds, while the Sun appears to perform the same revolution in 24 hours, so that the stars gain 3 minutes and 56 seconds upon the Sun every day. In a year, this amounts to a day, or, to the time taken by the Earth to perform one diurnal revolution. It, therefore, happens that, when time is measured by the stars, there are 366 days in the year, or, 366 diurnal revolutions of the Earth; while, if measured by the Sun from one meridian to another, there are only 365 whole days in the year. The former are called the *siderial*, and the latter *solar* days.

216. If the Earth had only a diurnal motion, her revolution, in respect to the Sun, would coincide exactly with the same revolution in respect to the stars; but, while she is making one revolution on her axis toward the east, she advances in the same direction about one degree in her orbit, so that to bring the same meridian toward the Sun, she must make a little more than one entire revolution.

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213. What two causes render the weights of bodies less at the equator than at the poles? 214. What would be the consequence on the weights of bodies at the equator, did the Earth turn over once in 84 minutes and 43 seconds? 215. The stars appear to move round the Earth in less time than the Sun: what does the difference amount to in a year? What is the year measured by a star called? What is that measured by the Sun called? 216. Had the Earth only a diurnal revolution, would the siderial and solar time agree?

217. Thus, the Earth must complete one revolution, and a portion of a second revolution, equal to the space she has advanced in her orbit, in order to bring the same meridian back again to the Sun. This small portion of a second revolution amounts daily to the 365th part of her circumference, and, therefore, at the end of the year, to one entire rotation; and, hence in 365 days, the Earth actually turns on her axis 366 times. Thus, as one complete rotation forms a siderial day, there must, in the year, be one siderial more than there are solar days, one rotation of the Earth, with respect to the Sun, being lost by the Earth's yearly revolution. The same loss of a day happens to a traveler, who, in passing round the Earth to the west, reckons his time by the rising and setting of the Sun. If he passes round toward the east, he will gain a day, for the same reason.

218. *Astronomical Riddle.*—Two persons, it is said, were born on the same day, in 1700, and both deceased on the same day, in 1760, having lived at the Cape of Good Hope. One would suppose, of course, that these persons were of exactly the same age, and yet, one had lived 100 days longer than the other. The solution is obvious from what we have just stated. These two persons had sailed around the world every year for 50 years; and, thus, while the one had gained a day by sailing to the east, the other had lost a day by sailing toward the west, thus making, between them, a difference of 100 days in their ages, though, in truth, they had both lived the same period of absolute time.

MEAN TIME.

219. *Equal*, or *mean* time, is that which is reckoned by a clock, supposed to indicate exactly 24 hours, from 12 o'clock on one day to 12 o'clock on the next day. *Apparent* time, is that which is measured by the apparent motion of the Sun, in the heavens, as indicated by a meridian line, or sun-dial.

220. Were the Earth's orbit a perfect circle, and her axis perpendicular to the plane of this orbit, the days would be of a uniform length, and there would be no difference between the clock and the Sun; both would indicate 12 o'clock at the same time, on every day in the year. But, on account of the inclination of the Earth's axis to the ecliptic, unequal portions of the

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217. How many times does the Earth turn on her axis in a year? Why does she turn more times than there are days in the year? 219. What is meant by equal or mean time? 220. Were the Earth's orbit a perfect circle, and her axis perpendicular to its plane, what would be the effect on time?

Sun's apparent path through the heavens will pass any meridian in equal times.

221. Thus the eliptical form of the Earth's orbit, her unequal motions, and the inclination of her axis, would prevent the agreement of the Sun and clock, except when the Earth is at the greatest distance from the Sun, which is on the 1st of July, and when she is at the least distance, which is on the 1st of January. From these causes the Sun would be faster than the clock, from the 1st of July to the 1st of January, and then slower than the clock, from the 1st of January to the 1st of July.

Now these two causes, which result from sources which can not be here explained, counteract each other, so that the Sun and clock agree only when they coincide, or balance each other, which takes place on, or about the 15th of April, the 15th of June, the 31st of August, and the 24th of December.

On these days the Sun and clock, keeping exact time, coincide, or as the Almanac says, are even.

222. The greatest differences between the Sun and clock, are on the 1st of November, when the clock is 16¼ minutes too fast, and on the 10th of February, when it is 14 minutes too slow.

THE MOON.

223. *While the Earth revolves round the Sun, the Moon revolves round the Earth, completing her revolution once in* 27 *days,* 7 *hours and* 43 *minutes, and at the distance of* 240,000 *miles from the Earth. The period of the Moon's change, that is, from new Moon to new Moon again, is* 29 *days,* 12 *hours, and* 44 *minutes.*

224. The time of the Moon's revolution round the Earth is called her *periodical* month; and the time from change to change is called her *synodical* month. If the Earth had no annual motion, these two periods would be equal; but because the Earth goes forward in her orbit, while the Moon goes round the Earth, the Moon must go as much further, from change to change, to make these periods equal, as the Earth goes forward during that time, which is more than a twelfth part of her orbit, there being more than twelve lunar periods in the year.

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221. What prevents the agreement of the Sun and clock? When do the Sun and clock agree? 222. When do they differ most? 223. What is the period of the Moon's revolution round the Earth? What is the period from new Moon to new Moon again? 224. What are these two periods called? Why are not the periodical and synodical months equal?

225. *We only see one Side of the Moon.*—The Moon always presents the same side, or face, toward the Earth, and hence it is evident that she turns on her axis but once, while she is performing one revolution round the Earth, so that the inhabitants of the Moon have but one day and night in the course of a lunar month.

One half of the Moon is never in the dark, because when this half is not enlightened by the Sun, a strong light is reflected to her from the Earth, during the Sun's absence. The other half of the Moon enjoys alternately two weeks of the Sun's light, and two weeks of total darkness.

PHASES OF THE MOON.—One of the most interesting circumstances to us, respecting the Moon, is the constant changes which she undergoes, in her passage around the Earth. When she first appears, a day or two after her change, we can see only a small portion of her enlightened side, which is in the form of a crescent; and at this time she is commonly called new Moon. From this period she goes on increasing, or showing more and more of her face every evening, until at last she becomes round, and her face is fully illuminated. She then begins again to decrease, by apparently losing a small section of her face, and the next evening another small section from the same part, and so on, decreasing a little every day, until she entirely disappears; and having been absent a day or two, reappears in the form of a crescent, or new Moon, as before.

226. When the Moon disappears, she is said to be in *conjunction*, that is, she is in the same direction from us with the Sun. When she is full, she is said to be in *opposition*, that is, she is in that part of the heavens opposite to the Sun, as seen by us.

227. The different appearances of the Moon from *new* to *full*, and from *full* to *change*, are owing to her presenting different portions of her enlightened surface toward us at different times. These appearances are called *phases* of the Moon, and are easily accounted for, and understood by the following figure.

228. Let S, *Fig.* 275, be the Sun, E the Earth, and A, B, C, D, E, the Moon in different parts of her orbit. Now when the Moon changes, or is in conjunction with the Sun, as at A, her dark side is turned toward the Earth, and she is invisible, as

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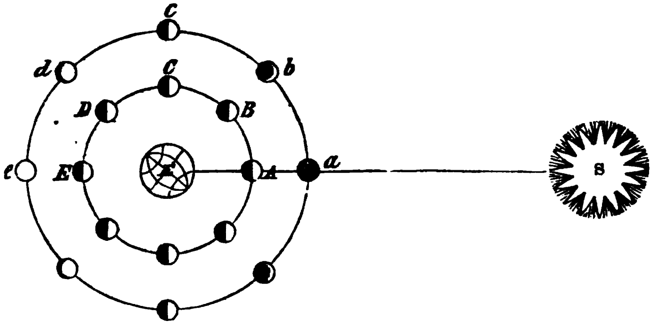
225. How is it proved that the Moon makes but one revolution on her axis, as she passes around the Earth? One half of the Moon is never in the dark; explain why this is so. How long is the day and night at the other half? How is it shown that the Moon shines only by reflected light? **226.** When is the Moon said to be in conjunction with the Sun, and when in opposition to the Sun? **227.** What are the phases of the Moon? **228.** Describe Fig. 275, and show how the Moon passes from change to full, and from full to change

FIG. 275



Phases of the Moon.

represented at *a*. The Sun always shines on one half of the Moon, in every direction, as represented at A and B, on the inner circle; but we at the Earth can see only such portions of the enlightened part as are turned toward us. After her change, when she has moved from A to B. a small part part of her illuminated side comes in sight, and she appears horned, as at *b*, and is then called the *new* Moon. When she arrives at C, several days afterward, one half of her disc is visible, and she appears as at *c*, her appearance being the same in both circles. At this point she is said to be in her *first quarter*, because she has passed through a quarter of her orbit, and is 90 degrees from the place of her conjunction with the Sun. At D, she shows us still more of her enlightened side, and is then said to appear *gibbous*, as at *d*. When she comes to E, her whole enlightened side is turned toward the Earth, and she appears in all the splendor of the *full* Moon. During the other half of her revolution she daily shows less and less of her illuminated side, until she again becomes invisible by her conjunction with the Sun. Thus in passing from her conjunction, *a*, to her full, *e*, the Moon appears every day to increase, while in going from her full to her conjunction again, she appears to us constantly to decrease, but as seen from the Sun, she appears always full.

229. *How the Earth appears at the Moon.*—The earth, seen by the inhabitants of the Moon, exhibits the same phases that

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229. What is said concerning the phases of the Earth, as seen from the Moon? When does the Earth appear full at the Moon?

the moon does to us, but in a contrary order. When the Moon is in her conjunction, and consequently invisible to us, the Earth appears full to the people of the Moon, and when the Moon is full to us, the Earth is dark to them.

230. *The Earth shines upon the Moon.*—That the Earth shines upon the Moon, as the Moon does upon us, is proved by the fact that the outline of her disc may be seen, when only a part of it is enlightened by the Sun. Thus when the sky is clear, and the moon only two or three days old, it is not uncommon to see the brilliant new Moon, with her horns enlightened by the Sun, and at the same time the old Moon faintly illuminated by reflection from the Earth. This phenomena is sometimes called "the old Moon in the new Moon's arms."

231. It was a disputed point among former astronomers, whether the Moon has an atmosphere; but the more recent discoveries have decided that she has an atmosphere, though there is reason to believe that it is much less dense than ours.

232. *Surface of the Moon.*—When the Moon's surface is examined through a telescope, it is found to be wonderfully diversified, for besides the dark spots perceptible to the naked eye, there are seen extensive valleys, and long ridges of highly elevated mountains. (See *Fig.*)

Some of these mountains, according to Dr. Herschel, are 4 miles high, while hollows more than three miles deep, and almost exactly circular, appear excavated on the plains. Astronomers have been at vast labor to enumerate, figure, and describe the mountains and spots on the surface of the Moon, so that the latitude and longitude of about 100 spots have been ascertained, and their names, shapes, and relative positions given. A still greater number of mountains have been named, and their heights and the lengths of their basis detailed.

233. The deep caverns, and broken appearance of the Moon's surface, long since induced astronomers to believe that such effects were produced by volcanoes, and more recent discoveries have seemed to prove that this suggestion was not without foundation.

ECLIPSES.

234. *Every planet and satellite in the Solar System, is illuminated by the Sun, and hence they cast shadows in the direction opposite to him, just as the shadow of a man reaches from the Sun.*

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230. How is it known that the Earth shines upon the Moon, as the Moon does upon us? 231. What is said concerning the Moon's atmosphere? 232. How high are some of the mountains, and how deep the caverns of the Moon? 233. What is said concerning the volcanoes of the Moon? 234. What is a lunar, and what a solar eclipse?

235. *Eclipses, what.*—Eclipses are of two kinds, namely, *Lunar*, an eclipse of the Moon, and *Solar*, an eclipse of the Sun. The first is occasioned by the shadow of the Earth on the Moon, and the second, by the shadow of the Moon on the Earth.

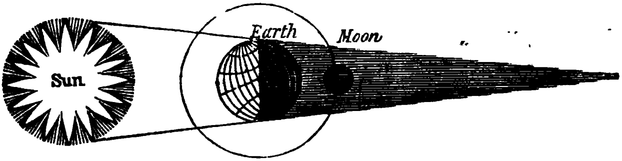
Hence, in both cases, the two planets and the Sun must be in nearly a straight line with respect to each other. In eclipses of the moon, the earth is between the Sun and Moon; and in eclipses of the Sun, the Moon is between the Earth and Sun.

LUNAR ECLIPSES.

236. *When the Moon falls into the shadow of the Earth, the rays of the Sun are intercepted, or hid from her, and she then becomes eclipsed.*

When the Earth's shadow covers only a part of her face, as seen by us, she suffers only a *partial* eclipse, one part of her disc being obscured, while the other part reflects the Sun's light. But when her whole surface is obscured by the Earth's shadow, she then suffers a *total* eclipse, and of a duration proportionate to the distance she passes through the Earth's shadow.

FIG. 276.



Eclipse of the Moon.

237. *Fig.* 276, represents a total lunar eclipse; the Moon being in the midst of the Earth's shadow. Now it will be apparent that in the situation of the Sun, Earth, and Moon, as represented in the figure, this eclipse will be visible from all parts of that hemisphere of the Earth which is next the Moon, and that the Moon's disc will be equally obscured, from whatever point it is seen. When the Moon passes through only a part of the Earth's shadow, then she suffers only a partial eclipse, but this is also visible from the whole hemisphere next the Moon. It will be remembered that lunar eclipses happen

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235. What occasions the lunar, and what the solar eclipse? 236. What is meant by a partial, and what a total eclipse? 237. Why is the same eclipse total at one place, and only partia' at another?

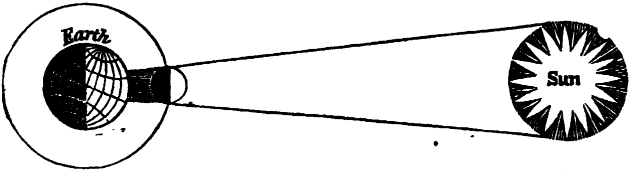
only at full Moon, the Sun and Moon being in opposition, and the Earth between them.

SOLAR ECLIPSES.

238. *When the Moon passes between the Earth and Sun, there happens an eclipse of the Sun, because then the Moon's shadow falls upon the Earth.*

239. A total eclipse of the Sun happens often, but when it occurs, the total obscurity is confined to a small part of the Earth; since the dark portion of the Moon's shadow never exceeds 200 miles in diameter on the Earth. But the Moon's partial shadow, or *penumbra*, may cover a space on the Earth of more than 4,000 miles in diameter, within all which space the Sun will be more or less eclipsed. When the penumbra first touches the Earth, the eclipse begins at that place, and ends when the penumbra leaves it. But the eclipse will be total only where the dark shadow of the Moon touches the Earth.

FIG. 277.



Eclipse of the Sun.

Fig. 277, represents an eclipse of the Sun, without regard to the penumbra, that it may be observed how small a part of the Earth the dark shadow of the Moon covers. To those who live within the limits of this shadow, the eclipse will be total, while to those who live in any direction around it, and within reach of the penumbra, it will be only partial.

240. Solar eclipses are called *annular*, from *annulus*, a ring, when the Moon passes across the center of the Sun, hiding all his light, with the exception of a ring on his outer edge, which the Moon is too small to cover from the position in which it is seen.

241. *Umbra and Penumbra.*—A solar eclipse, with the *pe-*

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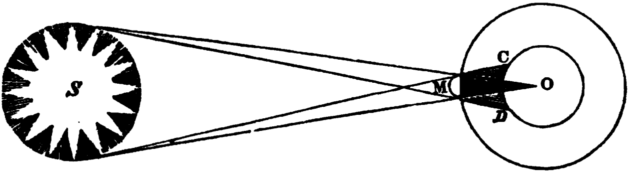
238. Why is a total eclipse of the Sun confined to so small a part of the Earth? 239. What is meant by penumbra? What will be the difference in the aspect of the eclipse, whether the observer stands within the dark shadow, or only within the penumbra? 240. What is meant by annular eclipses? Are annular eclipses ever total in any part of the Earth? In annular eclipses, what part of the Moon's shadow reaches the Earth? 241. What do penumbra, and umbra, mean?

numbra, or light and shadow, D C, and the *umbra*, or dark shadow, O, is seen in *Fig.* 278.

When the Moon is at its greatest distance from the Earth, its shadow, M O, sometimes terminates before it reaches the Earth, and then an observer standing directly under the point, O, will see the outer edge of the Sun, forming a bright ring around the circumference of the Moon, thus forming an *annular* eclipse.

FIG. 278.



The penumbra, D C, is only a partial interception of the Sun's rays, and in annular eclipses it is this partial shadow only which reaches the Earth, while the umbra, or dark shadow, terminates in the air. Hence annular eclipses are never total in any part of the Earth. The penumbra, as already stated, may cover more than 4,000 miles of space, while the umbra never covers more than 200 miles in diameter; hence partial eclipses of the Sun may be seen by a vast number of inhabitants, while comparatively few will witness the total eclipse.

242. When there happens a total solar eclipse to us, we are eclipsed to the Moon, and when the Moon is eclipsed to us, an eclipse of the Sun happens to the Moon. To the Moon, an eclipse of the Earth can never be total, since her shadow covers only a small portion of the Earth's surface. Such an eclipse, therefore, at the Moon, appears only as a dark spot on the face of the Earth; but when the moon is eclipsed to us, the Sun is partially eclipsed to the Moon for several hours longer than the Moon is eclipsed to us.

THE TIDES.

243. *The ebbing and flowing of the sea, which regularly takes place twice in* 24 *hours, are called the tides.*

244. The causes of the tides, is the attraction of the Sun and Moon, but chiefly of the Moon, on the waters of the ocean. In

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242. What is said concerning eclipses of the Earth as seen from the Moon? 243. What are the tides? 244. What is the cause of the tides?

virtue of the universal principle of gravitation, heretofore explained, the Moon, by her attraction, draws or raises the water toward her, but because the power of attraction diminishes as the squares of the distances increase, the waters on the opposite of the Earth, are not so much attracted as they are on the side nearest the Moon.

245. The want of attraction, together with the greater centrifugal force of the Earth, on its opposite side, produced in consequence of its greater distance from the common center of gravity, between the Earth and Moon, causes the waters to rise on the opposite side, at the same time that they are raised by direct attraction on the side nearest the Moon.

Thus the waters are constantly elevated on the sides of the Earth opposite to each other above their common level, and consequently depressed at opposite points equally distant from these elevations.

FIG. 279.

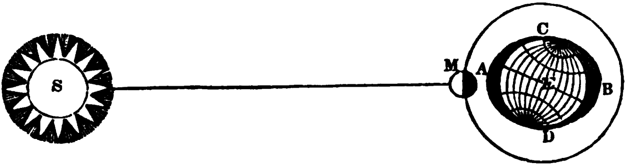

Illustration of the Tides.

246. Let M, *Fig.* 279, be the Moon, and E, the Earth, covered with water. As the Moon passes round the Earth, its solid and fluid parts are equally attracted by her influence according to their densities; but while the solid parts are at liberty to move only as a whole, the water obeys the slightest impulse, and thus tends toward the Moon where her attraction is the strongest. Consequently, the waters are perpetually elevated immediately under the Moon.

247. If, therefore, the Earth stood still, the influence of the Moon's attraction would raise the tides only as she passed round the Earth. But as the Earth turns on her axis every 24 hours, and as the waters nearest the Moon, as at A, are constantly elevated, they will in the course of 24 hours, move round the whole Earth, and consequently from this cause there will be high water at every place once in 24 hours. As the elevation of the waters under the Moon causes their depression at 90 de-

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245. What causes the tide to rise on the side of the Earth opposite to the Moon 246. Explain Fig. 279. 247. If the Earth stood still, the tides would rise only as the Moon passes round the Earth; what then causes the tides to rise twice in 24 hours?

grees distance on the opposite sides of the Earth, D and C, the point, C, will come to the same place, by the Earth's diurnal revolution, six hours after the point, A, because C is one quarter of the circumference of the Earth from the point, A, and therefore, there will be low water at any given place six hours after it was high water at that place.

248. But while it is high water under the Moon, in consequence of her direct attraction, it is also high water on the opposite side of the Earth in consequence of her diminished attraction, and the Earth's centrifugal motion, and therefore it will be high water from this cause twelve hours after it was high water from the former cause, and six hours after it was low water from both causes.

249. But while the Earth turns on her axis, the Moon advances in her orbit, and consequently any given point on the Earth will not come under the Moon on one day, so soon as it did on the day before. For this reason, high or low water at any place comes about fifty minutes later on one day than it did the day before.

Thus far we have considered no other attractive influence except that of the Moon, as affecting the waters of the ocean. But the Sun, as already observed, has an effect upon the tides, though on account of his great distance, his influence is small when compared with that of the Moon.

250. When the Sun and Moon are in conjunction, as represented in *Fig.* 279, which takes place at her change, or when they are in opposition, which takes place at full Moon, then their forces are united, or act on the waters in the same direction, and consequently the tides are elevated higher than usual, and on this account are called *spring tides.*

251. *Neap Tides.*—But when the Moon is in her quadratures, or quarters, the attraction of the Sun tends to counteract that of the Moon, and although his attraction does not elevate the waters and produce tides, his influence diminishes that of the Moon, and consequently the elevation of the waters are less when the Sun and Moon are so situated in respect to each other, than when they are in conjunction or opposition.

This effect is represented by *Fig.* 280, where the elevation of the tides at C and D is produced by the causes already explained; but their elevation is not so great as in *Fig.* 279, since

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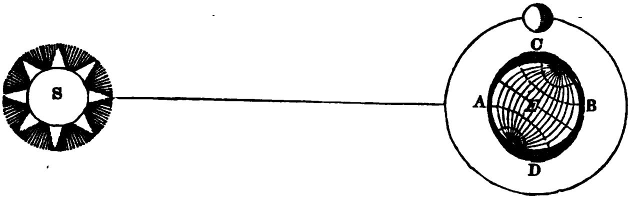
248. When it is high water under the Moon by her attraction, what is the cause of high water on the opposite side of the Earth, at the same time? 249. Why are the tides about fifty minutes later every day? 250. What produces spring tides? Where must the Moon be in respect to the Sun, to produce spring tides? 251. What is the occasion of neap tides?

the influence of the Sun acting in the direction, A B, tends to counteract the Moon's attractive influence. These small tides are called *neap tides*, and happen only when the Moon is in her quadratures.

FIG. 280.



Small, or Neap Tides.

The tides are not at their greatest heights at the time when the Moon is at its meridian, but some time afterward, because the water, having a motion forward, continues to advance by its own inertia, some time after the direct influence of the Moon has ceased to effect it.

LATITUDE AND LONGITUDE.

252. *Latitude is the distance from the equator in a direct line, north or south, measured in degrees and minutes.*

The number of degrees is 90 north, and as many south, each line on which these degrees are reckoned running from the equator to the poles. Places at the north of the equator are in *north latitude*, and those south of the equator are in *south latitude*. The *parallels* of latitude are imaginary lines drawn parallel to the equator, either north or south, and hence every place situated on the same parallel, is in the same latitude, because every such place must be at the same distance from the equator. The length of a degree of latitude is 60 geographical miles.

253. *Longitude is the distance measured in degrees and minutes, either east or west, from any given point on the equator, or on any parallel of latitude.* Hence the lines, or meridians of longitude, cross those of latitude at right angles. The degrees of longitude are 180 in number, its lines extending half a circle to the east, and half a circle to the west, from any given meridian, so as to include the whole circumference of the Earth.

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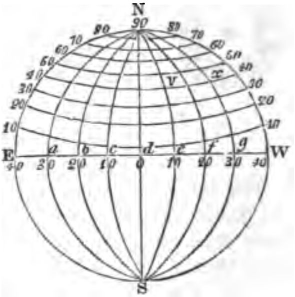
252. What is latitude? How many degrees of latitude are there? How far do the lines of latitude extend? What is meant by north and south latitude? What are the parallels of latitude? **253.** What is longitude? How many degrees of longitude are there, east or west? What is the latitude of any place? What is the longitude of a place?

A degree of longitude, at the equator, is of the same length as a degree of latitude, but as the poles are approached, the degrees of longitude diminish in length, because the Earth grows smaller in circumference from the equator toward the poles; hence the lines surrounding it become less and less. This will be made obvious by *Fig.* 281.

Let this figure represent the Earth, N being the north pole, S the south pole, and E W the equator. The lines 10, 20, 30, and so on, are the parallels of latitude, and the lines, N *a* S, N *b* S, &c, are meridian lines, or those of longitude.

FIG. 281.



Parallels of Longitude.

The latitude of any place on the globe, is the number of degrees between that place and the equator, measured on a meridian line: thus, *x* is in latitude 40 degrees, because the *x g* part of the meridian contains 40 degrees. The longitude of a place is the number of degrees it is situated east or west from any meridian line; thus, *v* is 20 degrees west longitude from *x*, and *x* is 20 degrees east longitude from *v*.

254. As the equator divides the Earth into two equal parts, or hemispheres, there seems to be a natural reason why the degrees of latitude should be reckoned from this great circle. But from east to west there is no natural division of the Earth, each meridian line being a great circle, dividing the Earth into two hemispheres, and hence there is no natural reason why longitude should be reckoned from one meridian any more than another. It has, therefore, been customary for writers and mariners to reckon longitude from the capital of their own country; as the English from London, the French from Paris, and the Americans from Washington. But this mode, it is apparent, must occasion much confusion, since each writer of a different nation would be obliged to correct the longitude of all other countries, to make it agree with his own. More recently, therefore, the writers of Europe and America have selected the royal observatory, at Greenwich, near London, as the first

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254. Why are the degrees of latitude reckoned from the equator? What is said concerning the places from which the degrees of longitude nave been reckoned? What is the inconvenience of estimating longitude from a place in each country? From what place is longitude reckoned in Europe and America?

meridian, and on most maps and charts lately published, longitude is reckoned from that place.

255. *How Latitude is Found.*—The latitude of any place is determined by taking the altitude of the Sun at mid-day, and then subtracting this from 90 degrees, making proper allowances for the Sun's place in the heavens. The reason of this will be understood, when it is considered that the whole number of degrees from the zenith to the horizon is 90, and therefore, if we ascertain the Sun's distance from the horizon, that is, his altitude, by allowing for the Sun's declination north or south of the equator, and subtracting this from the whole number, the latitude of the place will be found. Thus, suppose that on the 20th of March, when the Sun is at the equator, his altitude from any place north of the equator should be found to be 48 degrees above the horizon; this, subtracted from 90, the whole number of the degrees of latitude, leaves 42, which will be the latitude of the place where the observation was made.

256. If the Sun, at the time of observation, has a declination north or south of the equator, this declination must be added to, or subtracted from, the meridian altitude, as the case may be. For instance, another observation being taken at the place where the latitude was found to be 42, when the Sun had a declination of 8 degrees north, then his altitude would be 8 degrees greater than before, and therefore 56, instead of 48. Now, subtracting this 8, the Sun's declination, from 56, and the remainder from 90, and the latitude of the place will be found 42, as before. If the Sun's declination be south of the equator, and the latitude of the place north, his declination must be added to the meridian altitude instead of being subtracted from it. The same result may be obtained by taking the meridian altitude of any of the fixed stars, whose declinations are known, instead of the Sun's, and proceeding as above directed.

257. *How Longitude is Found.*—There is more difficulty in ascertaining the degrees of longitude, than those of latitude, because, as above stated, there is no fixed point, like that of the equator, from which its degrees are reckoned. The degrees of longitude are therefore estimated from Greenwich, and are ascertained by the following methods:—

258. When the Sun comes to the meridian of any place, it

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255. How is the latitude of a place determined? Give an example of the method of finding the latitude of the same place at different seasons of the year? 256. When must the Sun's declination from the equator be added to, and when subtracted from, his meridian altitude? 257. Why is there more difficulty in ascertaining the degrees of longitude than of latitude? 258. How many degrees of longitude does the surface of the Earth pass through in an hour?

is noon, or 12 o'clock, at that place, and therefore, since the equator is divided into 360 equal parts, or degrees, and since the Earth turns on its axis once in 24 hours, 15 degrees of the equator will correspond with one hour of time, for 360 degrees being divided by 24 hours, will give 15. The Earth, therefore, moves in her daily revolution, at the rate of 15 degrees for every hour of time. Now, as the apparent course of the Sun is from east to west, it is obvious that he will come to any meridian lying east of a given place, sooner than to one lying west of that place, and therefore it will be 12 o'clock to the east of any place, sooner than at that place, or to the west of it.

259. When, therefore, it is noon at any one place, it will be 1 o'clock at all places 15 degrees to the east of it, because the Sun was at the meridian of such places an hour before; and so, on the contrary, it will be 11 o'clock, 15 degrees west of the same place, because the Sun has still an hour to travel before he reaches the meridian of that place. It makes no difference, then, where the observer is placed, since, if it is 12 o'clock where he is, it will be 1 o'clock, 15 degrees to the east of him, and 11 o'clock, 15 degrees to the west of him, and so in this proportion, let the time be more or less. Now, if any celestial phenomenon should happen, such as an eclipse of the Moon, or of Jupiter's satellites, the difference of longitude between two places where it is observed, may be determined by the difference of the times at which it appeared to take place. Thus, if the Moon enters the Earth's shadow at 6 o'clock in the evening, as seen at Philadelphia, and at half past 6 o'clock at another place, then this place is half an hour, or 7½ degrees, to the east of Philadelphia, because 7½ degrees of longitude are equal to half an hour of time. To apply these observations practically, it is only necessary that it should be known exactly at what time the eclipse takes place at a given point on the Earth.

260. USE OF THE CHRONOMETER.—Suppose two chronometers, which are known to go at exactly the same rate, are made to indicate 12 o'clock by the meridian line at Greenwich, and the one be taken to sea, while the other remains at Greenwich. Then suppose the captain, who takes his chronometer to sea, has occasion to know his longitude. In the first place, he ascertains, by an observation of the Sun, when it is 12 o'clock at the place where he is, and then by his time-piece, when it is 12 o'clock at Greenwich, and by allowing 15 degrees for every

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259. Suppose it is noon at any given place, what o'clock will it be fifteen degrees to the east of that place? Explain the reason. How may longitude be determined by an eclipse? 260. Explain the principles on which longitude is determinined by the chronometer.

hour of the difference in time, he will know his precise longitude in any part of the world.

261. For example, suppose the captain sails with his chronometer for America, and after being several weeks at sea, finds by observation that it is 12 o'clock by the Sun, and at the same time finds by his chronometer, that it is 4 o'clock at Greenwich. Then, because it is noon at his place of observation after it is noon at Greenwich, he knows that his longitude is west from Greenwich, and by allowing 15 degrees for every hour of the difference, his longitude is ascertained. Thus, 15 degrees, multiplied by 4 hours, give 60 degrees of west longitude from Greenwich. If it is noon at the place of observation, before it is noon at Greenwich, then the captain knows that his longitude is east, and his true place is found in the same manner.

FIXED STARS.

262. *The stars are called fixed, because they have been observed not to change their places with respect to each other.* They may be distinguished by the naked eye from the planets of our system by their scintillations, or twinkling. The stars are divided into classes, according to their magnitudes, and are called stars of the first, second, and so on to the sixth magnitude. About 2,000 stars may be seen with the naked eye in the whole vault of the heavens, though only about 1,000 are above the horizon at the same time. Of these, about 17 are of the first magnitude, 50 of the second magnitude, and 150 of the third magnitude. The others are of the fourth, fifth, and sixth magnitudes, the last of which are the smallest that can be distinguished with the naked eye.

263. It might seem incredible, that on a clear night only about 1,000 stars are visible, when on a single glance at the different parts of the firmament, their numbers appear innumerable. But this deception arises from the confused and hasty manner in which they are viewed; for if we look steadily on a particular portion of sky, and count the stars contained within certain limits, we shall be surprised to find their number so few.

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261. Suppose the captain finds by his chronometer that it is 12 o'clock, where he is 6 hours later than at Greenwich, what then would be his longitude? Suppose he finds it to be 12 o'clock, 4 hours earlier where he is, than at Greenwich, what then would be his longitude? **262.** Why are the stars called fixed? How may the stars be distinguished from the planets? The stars are divided into classes, according to their magnitudes; how many classes are there? How many stars may be seen with the naked eye in the whole firmament? **263.** Why does there appear to be more stars than there really are?

264. The nearest fixed stars to our system, from the most accurate astronomical calculations, can not be nearer than 20,000,000,000,000, or 20 trillions of miles from the Earth, a distance so immense, that light can not pass through it in less than three years. Hence, were these stars annihilated at the present time, their light would continue to flow toward us, and they would appear to be in the same situation to us, three years hence, that they do now.

265. Our Sun, seen from the distance of the nearest fixed stars, would appear no larger than a star of the first magnitude does to us. These stars appear no larger to us, when the Earth is in that part of her orbit nearest to them, than they do, when she is in the opposite part of her orbit; and as our distance from the Sun is 95,000,000 of miles, we must be twice this distance, or the whole diameter of the Earth's orbit, nearer a given fixed star at one period of the year than at another. The difference, therefore, of 190,000,000 of miles, bears so small a proportion to the whole distance between us and the fixed stars, as to make no appreciable difference in their sizes, even when assisted by the most powerful telescopes.

266. The amazing distances of the fixed stars may also be inferred from the return of comets to our system, after an absence of several hundred years.

The velocity with which some of these bodies move, when nearest the Sun, has been computed at nearly a million of miles in an hour, and although their velocities must be perpetually retarded, as they recede from the Sun, still, in 250 years of time, they must move through a space which to us would be infinite. The periodical return of one comet is known to be upward of 500 years, making more than 250 years in performing its journey to the most remote part of its orbit, and as many in returning back to our system; and that it must still always be nearer our system than the fixed stars, is proved by its return; for by the laws of gravitation, did it approach nearer another system it would never again return to ours.

267. From such proofs of the vast distances of the fixed stars, there can be no doubt that they shine with their own light, like our Sun, and hence the conclusion that they are Suns to other worlds, which move around them, as the planets do

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264. What is the computed distance of the nearest fixed stars from the Earth? How long would it take light to reach us from the fixed stars? **265.** How large would our Sun appear at the distance of the fixed stars? What is said concerning the difference of the distance between the Earth and the fixed stars at different seasons of the year, and of their different appearance in consequence? **266.** How may the distances of the fixed stars be inferred, by the long absence and return of comets? **267.** On what ground is it supposed that the fixed stars are Suns to other worlds?

around our Sun. Their distances will, however, prevent our ever knowing, except by conjecture, whether this is the case or not, since, were they millions of times nearer us than they are, we should not be able to discover the reflected light of their planets.

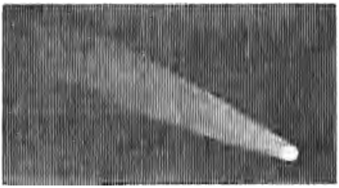
COMETS.

268. This word is from the Greek, *coma*, meaning *hair*, because many of these bodies seem to be composed of fibrous matter, like hair. They are also called *wandering* stars, because they pass through the heavens in different directions, never being known to stop any where.

269. *Number and Periods of Comets.*—The number of comets is unknown, though some astronomers suppose that there are nearly 500 belonging to our system. Ferguson, who wrote in about 1760, supposed that there were less than 30 comets which made us occasional visits; but since that period the elements of the orbits of nearly 100 of these bodies have been computed.

Of these, however, there are only three whose periods of return among us are known with any degree of certainty. The first of these has a period of 75 years; the second a period of 129 years; and the third a period of 575 years. The third appeared in 1680, and therefore can not be expected again until the year 2225. This comet, *Fig.* 282, in 1680, excited the most intense interest among the astronomers of Europe, on account of its great apparent size and near approach to our system. In the most remote part of its orbit, its distance from the Sun was estimated at about 11,200,000,000 of miles. At its nearest approach to the Sun, which was only about 50,000 miles, its velocity, according to Sir Isaac Newton, was 880,000 miles in an hour; and supposing it to have retained the Sun's heat, like other solid bodies, its temperature must have been about 2,000 times that of red hot iron. The tail of this comet was at least 100,000,000 of miles long.

FIG. 282.



Comet of 1680.

270. In the Edinburgh Encyclopedia, article *Astronomy*, there

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269. What number of comets are supposed to belong to our system?

is the most complete table of comets yet published. This table contains the elements of 97 comets, calculated by different astronomers, down to the year 1808.

From this table it appears that 24 comets have passed between the Sun and the orbit of Mercury; 33 between the orbits of Venus and the Earth; 15 between the orbits of the Earth and Mars; 3 between the orbits of Mars and Ceres; and 1 between the orbits of Ceres and Jupiter. It also appears by this table that 49 comets have moved round the Sun from west to east, and 48 from east to west.

271. *Nature of Comets.*—Of the nature of these wandering planets, very little is known. When examined by a telescope, they appear like a mass of vapors surrounding a dark nucleus. When the comet is at its perihelion, or nearest the Sun, its color seems to be heightened by the intense light or heat of that luminary, and it then often shines with more brilliancy than the planets. At this time the tail or train, which is always directly opposite to the Sun, appears at its greatest length, but is commonly so transparent as to permit the fixed stars to be seen through it. A variety of opinions have been advanced by astronomers concerning the nature and causes of these trains, but no satisfactory theory has been offered.

A new comet was discovered by Miss Maria Mitchell, of Nantucket, in October, 1847, for which she received the gold medal of the king of Denmark, offered for the first discovery of a new comet in any country.

272. Expected Comet.—Astronomers have recently made observations about the return of a great comet, the period of which is 300 years; having been observed, A. D. 104, 292, 682, and in 1264, the next appearance being in 1856. But on the exact time of its arrival so as to be seen from our Earth, astronomers seem to have come to different results; but, by the most recent and reliable German calculations, it may be expected in August, 1858.

PARALLAX.

273. Parallax is the difference between the true and apparent place of a celestial body. The *apparent* place is that in which the body seems to be when viewed from the surface of the Earth, the *true* place being that in which it would appear if seen from the center of the Earth.

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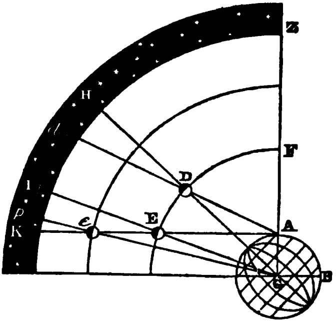
270. How many have had the elements of their orbits estimated by astronomers? How many are there whose periods of return are known? 271. What is said of the comet of 1680? 273. What is a parallax? What is the apparent place of a celestial body? What is the true place of such a body?

FIG. 283.



Diurnal Parallax.

This will be understood by *Fig.* 283, where if we suppose a spectator placed at G, in the Earth's center, he would see the Moon, E, among the stars at I, whereas without changing the position of the Moon, if that body is seen from A, on the surface of the Earth, it would appear among the stars at K. Now I is the *true*, and K the *apparent* place of the Moon, the space between them, being the Moon's parallax.

The parallax of a body is greatest when on the sensible horizon, (182,) or at the moment when it becomes visible to the eye. From this point it diminishes until it reaches the zenith, or the highest place in the heavens, when its parallax ceases entirely. Thus it will be seen by the figure, that the parallax of the moon is less when at D, than it was at E, and that when it arrives at the zenith, Z, its position is the same whether seen from the center of the Earth, G, or from its surface, A.

The greater the distance of the heavenly body from the spectator, the less is its parallax.

Thus were the Moon at *e* instead of at E, her parallax would be only equal to *p* K, instead of I K. Hence the Moon, being the nearest celestial body, has the greatest parallax, the difference of her place among the stars, when seen from the surface of the Earth, A, and the center, G, being about 4,000 miles.

274. *Parallax of the Stars.*—The stars are at such immense distances from the Earth, that the difference of station between the center and surface of the Earth makes no perceptible change in their places, and hence they have no parallax.

275. *Diurnal Parallax.*—This applies to the solar system, and takes place every day in the apparent rotation of the planets around the Earth. The Moon, as above shown, has a parallax when she rises, which diminishes until she reaches the zenith, when it ceases entirely; the same is the case with the Sun and planets, which have sensible parallaxes.

276. *Annual Parallax.*—This is the difference in the appa-

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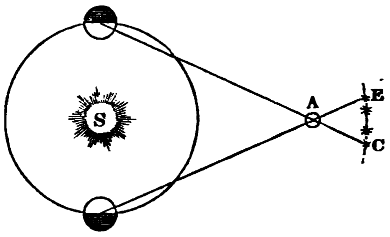
273. Explain Fig. 283. and show why there is no parallax when the body is in the zenith 274. Why have the stars no parallaxes? 275. What is diurnal parallax?

rent places of the celestial bodies, as seen from the Earth at the opposite points of her orbit, during her annual revolution round the Sun.

FIG. 284.



Annual Parallax.

Suppose A, *Fig.* 284, to be a stationary celestial object, then as the Earth makes her annual revolution around the Sun, S, this object at one time will appear among the stars at E, but six months after, when the Earth comes to the opposite point in her orbit, the same object will be seen at C, the space from C to E being the annual parallax of the object, A. But the distances of the stars are so great that the diameter of the Earth's orbit, or 190,000,000 of miles make no difference in their apparent places. Were the fixed stars within 19,000,000,000,000, or 19 trillions of miles, their distance could be told by their parallaxes.

By means of the most refined mathematical calculations, European astronomers have recently determined the parallaxes of several of the fixed stars.

CHAPTER XIII.

ELECTRICITY.

277. The science of *Electricity*, which now ranks as an important branch of Natural Philosophy, is wholly of modern date. The ancients were acquainted with a few detached facts dependent on the agency of electrical influence, but they never imagined that it was extensively concerned in the operations of nature, or that it pervaded material substances generally. The term electricity is derived from *electron*, the Greek name of amber, because it was known to the ancients, that when that substance was rubbed or excited, it attracted or repelled small light bodies, but it was then unknown that other substances, when excited, would do the same.

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276. What is annual parallax? 277. From what is the term electricity derived?

When a piece of glass, sealing-wax, or amber, is rubbed with a dry hand, and held toward small and light bodies, such as threads, hairs, feathers, or straws, these bodies will fly toward the surface thus rubbed, and adhere to it for a short time. The influence by which these small substances are drawn, is called *electrical attraction;* the surface having this attractive power is said to be *excited;* and the substances susceptible of this excitation, are called *electrics.* Substances not having this attractive power when rubbed, are called *non-electrics.*

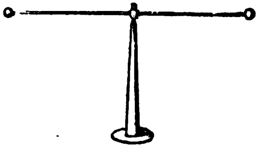
278. The principal electrics are amber, resin, sulphur, glass, the precious stones, sealing-wax, and the fur of quadrupeds. But the metals, and many other bodies, may be excited when insulated and treated in a certain manner.

After the light substances which had been attracted by the excited surface, have remained in contact with it a short time, the force which brought them together ceases to act, or acts in a contrary direction, and the light bodies are *repelled*, or thrown away from the excited surface. Two bodies, also, which have been in contact with the excited surface, mutually repel each other.

279. *Electroscope.*—Various modes have been devised for exhibiting distinctly the attractive and repulsive agencies of electricity, for obtaining indications of its presence, when it exists only in a feeble degree. Instruments for this purpose are termed *Electroscopes.*

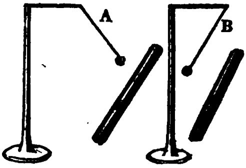
One of the simplest instruments of this kind consists of a metallic needle, terminated at each end by a light pith-ball, which is covered with gold leaf, and supported horizontally at its center by a fine point, *Fig.* 285. When a stick of sealing-wax, or a glass tube, is excited, and then presented to one of these balls, the motion of the needle on its pivot will indicate the electrical influence.

FIG. 285.



Electroscope.

FIG. 286.



Electrical Attraction.

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277. What is electrical attraction? What are electrics? What are non-electrics? 278. What are the principal electrics? What is meant by electrical repulsion? 279. What is an electroscope?

280. If an excited substance be brought near a ball made of pith, or cork, suspended by a silk thread, the ball will, in the first place approach the electric, as at A, *Fig.* 286, indicating an attraction toward it, and if the position of the electric will allow, the ball will come into contact with the electric, and adhere to it for a short time, and will then recede from it, showing that it is repelled, as at B. If, now, the ball which had touched the electric, be brought near another ball, which has had no communication with an excited substance, these two balls will attract each other, and come into contact; after which they will repel each other, as in the former case.

It appears, therefore, that the excited body, as the stick of sealing-wax, imparts a portion of its electricity to the ball, and that then the ball is also electrified, a mutual repulsion then takes place between them. Afterwards, the ball, being electrified by contact with the electric, when brought near another ball not electrified, transfers a part of its electrical influence to that, after which these two balls repel each other, as in the former instance.

281. Thus, when one substance has a greater or less quantity of electricity than another, it will attract the other substance, and when they are in contact will impart to it a portion of this superabundance; but when they are both equally electrified, both having more or less than their natural quantity of electricity, they will repel each other.

Electrical Theories.—To account for these phenomena, two theories have been advanced, one by Dr. Franklin, who supposes there is only one electrical fluid, and the other by Du Fay, who supposes that there are two distinct fluids.

282. *Franklin's Theory.*—Dr. Franklin supposed that all terrestrial substances were pervaded with the electrical fluid, and that by exciting an electric, the equilibrium of this fluid was destroyed, so that one part of the excited body contained more than its natural quantity of electricity, and the other part less. If in this state a conductor of electricity, as a piece of metal, be brought near the excited part, the accumulated electricity would be imparted to it, and then this conductor would receive more than its natural quantity of the electric fluid. This he called *positive* electricity. But if a conductor be connected with that part which has less than its ordinary share of the fluid, then

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280. When do two electrified bodies attract, and when do they repel each other? 281. How will two bodies act, one having more and the other less, than the natural quantity of electricity, when brought near each other? How will they act when both have more or less than their natural quantity? 282. Explain Dr. Franklin's theory of electricity. What is meant by positive, and what by negative electricity?

the conductor parts with a share of its own, and therefore will then contain less than its natural quantity. This he called *negative* electricity. When one body *positively* and another *negatively* electrified, are connected by a conducting substance, the fluid rushes from the positive to the negative body, and the equilibrium is restored.

283. *Du Fay's Theory.*—The other theory is explained thus. When a piece of glass is excited and made to touch a pith-ball, as above stated, then that ball will attract another ball, after which they will mutually repel each other, and the same will happen if a piece of sealing-wax be used instead of the glass. But if a piece of excited glass, and another of wax, be made to touch two separate balls, they will attract each other; that is, the ball which received its electricity from the wax will attract that which received its electricity from the glass, and will be attracted by it. Hence, Du Fay concludes that electricity consists of two distinct fluids, which exist together in all bodies—that they have a mutual attraction for each other—that they are separated by the excitation of electrics, and that when thus separated, and transferred to non-electrics, as to the pith-balls, their mutual attraction causes the balls to rush toward each other. These two principles he called *vitreous* and *resinous* electricity. The vitreous being obtained from glass, and the resinous from wax and other resinous substances.

Dr. Franklin's theory is by far the most simple, and will account for most of the electrical phenomena equally well with that of Du Fay, and therefore has been adopted by the most able and recent electricians.

284. *Conductors.—Metallic Conductors.*—It is found that some substances conduct the electric fluid from a positive to a negative surface with great facility, while others conduct it with difficulty, and others not at all. Substances of the first kind are called *conductors*, and those of the last *non-conductors*. The electrics, or such substances as, being excited, communicate electricity, are all non-conductors, while the non-electrics, or such substances as do not communicate electricity on being merely excited, are conductors. The conductors are the metals, charcoal, water, and the other fluids, except the oils; also, smoke, steam, ice, and snow. The best conductors are gold, silver, platina, brass, and iron.

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282. What is the consequence, when a positive and a negative body are connected by a conductor? **283.** Explain Du Fay's theory. When two balls are electrified, one with glass and the other with wax, will they attract or repel each other? What are the two electricities called? From what substances are the two electricities obtained? **284.** What are conductors? What are non-conductors? What substances are conductors? What substances are the best conductors?

Non-Conductors.—The electrics, or non-conductors, are glass, amber, sulphur, resin, wax, most hard stones, and the furs of some animals.

A body is said to be *insulated*, when it is supported or surrounded by an electric. Thus, a stool standing on glass legs, is insulated, and a plate of metal laid on a plate of glass, is insulated.

285. *Electrical Machines.*—When large quantities of the electric fluid are wanted for experiment, or for other purposes, it is procured by an *electrical machine.* These machines are of various forms, but all consist of an *electric* substance of considerable dimensions; the *rubber* by which this is excited; the *prime conductor*, on which the electric matter is accumulated; the *insulator*, which prevents the fluid from escaping; and machinery, by which the electric is set in motion.

Formerly a glass cylinder was employed as an electric, but more recently, round, flat plates of glass, called *plate machines*, are used instead of cylinders. This is a great improvement, since both sides of the plate are exposed to electrical friction, while in the cylinder, the outside only could be excited.

This machine is represented by *Fig.* 287, and consists of a circular plate of glass, from one to two or three feet in diameter, turning on an axis of wood, which passes through its center. The plate is rubbed, as it revolves, by two leather cushions, *a*

FIG. 287.

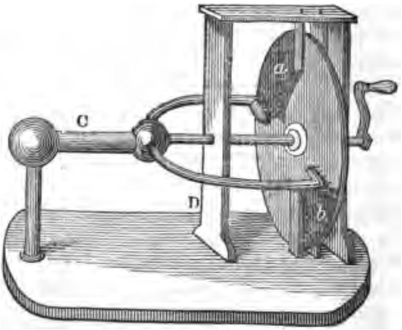

Plate Electrical Machine.

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284. What substances are electrics, or non-conductors ? When is a body said to be insulated ? 285. What are the several parts of an electrical machine ? Describe the electrical machine, Fig. 287.

and *b*, fixed at opposite points of its circumference; and, by means of elastic slips of wood, adjusted by screws, made to press on its surface. On the opposite side are two other cushions, not seen, the plate revolving between them. A hollow brass prime conductor, C, supported by a glass standard, D, is attached to the frame of the machine. On each side of the conductor are branches of the same metal, at the ends of which are sharp wires nearly touching the glass plate, and by means of which the electric fluid is collected and conveyed to the conductor.

286. *Mode of Action.*—The manner in which this machine acts is easily understood. The friction of the cushions against the glass plate, transfers the electrical fluid from the cushions to the glass, so that, while the glass becomes positive, the cushions become negative. Meantime, the fluid, which adheres to the surface of the glass, is attracted by the metallic points and conveyed to the prime conductor, which being insulated by the glass standard, the electricity is there accumulated in quantities proportionate to the surface of the conductor.

287. If the cushions are insulated, the quantity of electricity obtained is limited, consisting of that, merely, which the cushions contained; and, when this is transferred to the plate, no more can be obtained. It is then necessary to make the cushions communicate with the ground, the great reservoir of electricity, by laying the chain attached to the cushions on the floor or table, when, on again turning the machine, more of the fluid will be conveyed to the conductor.

288. *Insulated Persons.*—If two persons stand on two insulated stools, or if they both stand on a plate of glass, or a cake of wax, the one person being connected by the chain with the prime conductor, and the other with the cushion; then, after working the machine, if they touch each other, a strong shock will be felt, because the difference between their electrical states will be greater, the one having more and the other less than his natural quantity of electricity. But, if the two insulated persons both take hold of the chain connected with the prime conductor, or with that connected with the cushion, no spark will pass between them, on touching each other, because they will then both be in the same electrical state.

289. We have seen, *Fig.* 286, that the pith-ball is first attracted, and then repelled, by the excited electric, and that the

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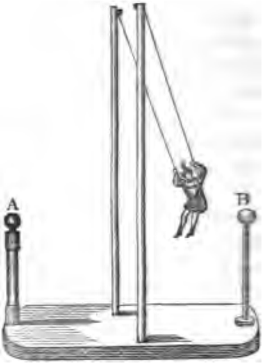
287. Whence comes the electricity, when the plate is turned? Why is it necessary to throw the chain on the ground to obtain more electricity? **288.** If two insulated persons take hold of the two chains, one connected with the prime conductor, and the other with the cushion, what changes will be produced? If an insulated person takes the chain what effect will it produce on him?

ball so repelled will attract, or be attracted, by other substances in its vicinity, in consequence of having received from the excited body more than its ordinary quantity of electricity.

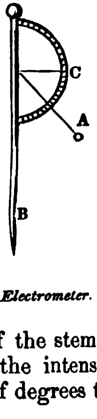
FIG. 288.



Electrical Swing.

290. *Electrical Swing.*—An amusing experiment may be made by means of the apparatus, *Fig.* 288. A little figure of a man is suspended between two small posts of wood or glass. The insulated brass ball, A, is connected with the prime conductor, while the opposite ball, B, communicates with the earth. The figure on silken cords is first drawn towards A, where it takes an electrical charge, which is discharged at B; and, thus, the little man becomes, as it were, animated, and which he seems highly to enjoy, and does so as long as he is supplied with electricity.

FIG. 289.



Electrometer.

291. *Electrometer.*—Instruments designed to measure the intensity of electric action are called *Electrometers.* Such an instrument is represented by *Fig.* 289. It consists of a slender rod of light wood, A, terminated by a pith-ball, which serves as an index. This is suspended at the upper part of the wooden stem, B, so as to play easily backward and forward. The ivory semi-circle, C, is affixed to the stem, having its center coinciding with the axis of motion of the rod, so as to measure the angle of deviations from the perpendicular, which the repulsion of the ball from the stem produces on the index.

When this instrument is used, the lower end of the stem is set into an aperture in the prime conductor, and the intensity of the electric action is indicated by the number of degrees the index is repelled from the perpendicular.

The passage of the electric fluid through a perfect conductor is never attended with light, or the crackling noise which is

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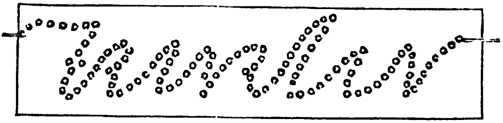
291. What is an electrometer? Describe that represented in Fig. 289, together with the mode of using it. When the electric fluid passes along a perfect conductor, is it attended with light or not? When it passes along an electric, or through the air, what phenomena does it exhibit?

heard when it is transmitted through the air, or along the surface of an electric.

292. *Fragments of Tin-foil.*—Several curious experiments illustrate this principle; for, if fragments of tin-foil, or other metal, be pasted on a piece of glass, so near each other that the electric fluid can pass between them, the whole line, thus formed with the pieces of metal, will be illuminated by the passage of the electricity from one to the other.

FIG. 290.



Franklin.

In this manner, figures or words may be formed, as in *Fig.* 290, which, by connecting one of its ends with the prime conductor, and the other with the ground, will, when the electric fluid is passed through the whole, in the dark, appear one continuous and vivid line of fire.

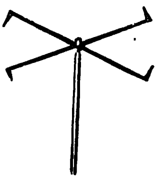
ELECTRICAL LIGHT.

293. Electrical light seems not to differ, in any respect, from the light of the Sun, or of a burning lamp. Dr. Wallaston observed that, when this light was seen through a prism, the ordinary colors arising from the decomposition of light were obvious.

294. When the electric fluid is discharged from a point, it is always accompanied by a current of air, whether the electricity be positive or negative. The reason of this appears to be, that the instant a particle of air becomes electrified, it repels, and is repelled by the point from which it received the electricity.

Several curious little experiments are made on this principle. Thus, let two cross-wires, as in *Fig.* 291, be suspended on a pivot, each having its point bent in a

FIG. 291.



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292. Describe the experiment, Fig. 290, intended to illustrate this principle. 293. What is the appearance of electrical light through a prism? 294. Describe Fig. 291, and explain the principle on which its motion depends.

contrary direction, and electrified by being placed on the prime conductor of a machine. These points, so long as the machine is in action, will give off streams of electricity; and, as the particles of air repel the points by which they are electrified, the little machine will turn round rapidly in the direction contrary to that of the stream of electricity. Perhaps, also, the reaction of the atmosphere against the current of air given off by the points, assists in giving it motion.

295. *Leyden Vials.*—When one part or side of an electric is positively, the other part or side is negatively electrified. Thus, if a plate of glass be positively electrified on one side, it will be negatively electrified on the other; and, if the inside of a glass vessel be positive, the outside will be negative.

Advantage of this circumstance is taken in the construction of electrical jars, called, from the place where they were first made, *Leyden vials.*

The most common form of this jar is represented by *Fig.* 292. It consists of a glass vessel, coated on both sides up to A, with tin-foil; the upper part being left naked, so as to prevent a spontaneous discharge, or the passage of the electric fluid from one coating to the other. A metallic rod, rising two or three inches above the jar, and terminated at the top with a brass ball, which is called the *knob* of the jar, is made to descend through the cover, till it touches the interior coating. It is along this rod that the charge of electricity is conveyed to the inner coating, while the outer coating is made to communicate with the ground.

FIG. 292.

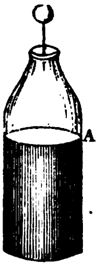
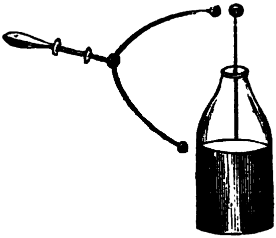


FIG. 293.



Leyden Jars.

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295. Suppose one part or side of an electric is positive, what will be the electrical state of the other side or part? What part of the electrical apparatus is constructed on this principle? How is the Leyden vial constructed? Why is not the whole surface of this vial covered with the tin-foil?

296. When a chain is passed from the prime conductor of an electrical machine to this rod, the electricity is accumulated on the tin-foil coating, while the glass above the tin-foil prevents its escape, and thus the jar becomes charged. By connecting together a sufficient number of these jars, any quantity of the electric fluid may be accumulated. For this purpose, all the interior coatings of the jars are made to communicate with each other, by metallic rods passing between them, and finally terminating in a single rod. A similar union is also established, by connecting the external coats with each other. When thus arranged, the whole series may be charged, as if they formed but one jar, and the whole series may be discharged at the same instant. Such a combination of jars is termed an *electrical battery.*

For the purpose of making a direct communication between the inner and outer coating of a single jar or battery, by which a discharge is effected, an instrument called a *discharging-rod* is employed. It consists of two bent metallic rods, terminated at one end by brass balls, and at the other end connected by a joint. This joint is fixed to the end of a glass handle, and, the rods being movable at the joint, the balls can be separated or brought near each other, as occasion requires. When opened to a proper distance, one ball is made to touch the tin-foil on the outside of the jar, and then the other is brought into contact with the knob of the jar, as seen in *Fig.* 293. In this manner a discharge is effected, or an equilibrium produced between the positive and negative sides of the jar.

297. *Shock felt by many Persons.*—Any number of persons may receive the electrical shock, by taking hold of each other's hand, the first person touching the knob, while the last takes hold of a chain connected with the external coating. In this manner, hundreds, or, perhaps, thousands of persons, will feel the shock at the same instant, there being no perceptible interval in the time when the first and the last person in the circle feels the sensation excited by the passage of the electric fluid.

298. *Atmospheric Electricity.*—The atmosphere always contains more or less electricity, which is sometimes positive, and at others negative. It is, however, most commonly positive, and always so when the sky is clear or free from clouds or fogs. It is always stronger in winter than in summer, and during the

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296. How is a Leyden vial charged? In what manner may a number of these vials be charged? What is an electrical battery? 297. Explain the design of Fig. 293, and show how an equilibrium is produced by the discharging-rod? What circumstance is related, which shows the surprising velocity with which electricity is transmitted? 298. Is the electricity of the atmosphere positive or negative? At what times does the atmosphere contain most electricity?

day than during the night. It is also stronger at some hours of the day than at others; being strongest about 9 o'clock in the morning, and weakest about the middle of the afternoon. These different electrical states are ascertained by means of long metallic wires extending from one building to another, and connected with electrometers.

299. It was proved by Dr. Franklin, that the electric fluid and *lightning* are the same substance, and this identity has been confirmed by subsequent writers on this subject.

300. LIGHTNING RODS.—Buildings may be secured from the effects of lightning, by fixing to them a metallic rod, which is elevated above any part of the edifice and continued to the moist ground, or to the nearest water. Copper, for this purpose, is better than iron, not only because it is less liable to rust, but because it is a better conductor of the electric fluid. The upper part of the rod should end in several fine points, which must be covered with some metal not liable to rust, such as gold, platina, or silver.

301. *No protection is afforded by the conductor, unless it is continued without interruption from the top to the bottom of the building, and it can not be relied on as a protector, unless it reaches the moist earth, or ends in water connected with the earth.* Conductors of copper may be three-fourths of an inch in diameter, but those of iron should be at least an inch in diameter. In large buildings, complete protection requires many lightning rods, or that they should be elevated to a height above the building in proportion to the smallness of their numbers, for modern experiments have proved that a rod only protects a circle around it, *the radius of which is equal to twice its length above the building.*

302. Thus a rod 20 feet above the building, will protect a space of 40 feet from it in all directions.

HYDRO-ELECTRICAL MACHINE.

303. A few years since, a workman at Newcastle, England, having to adjust a safety valve of a steam-engine, in order to prevent the escape of the steam, was astonished to receive a powerful shock of electricity on his hand, at the instant when it was enveloped in escaping steam.

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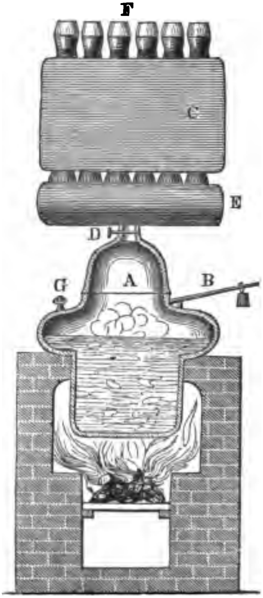
298. How are the different electrical states of the atmosphere ascertained? 299. Who first discovered that electricity and lightning were the same? What phenomena are mentioned which belong in common to electricity and lightning? 300. How may buildings be protected from the effects of lightning? Which is the best conductor, iron or copper? 301. What circumstances are necessary, that the rod may be relied on as a protector? 302. What diameter will a rod 20 feet above the building protect?

Mr. Armstrong, a man of science, in that place, on hearing the workman's account, proceeded at once to investigate a phenomenon so extraordinary, and before unknown; and it is to him that the scientific world is indebted for nearly all that is known on this curious subject.

The cut, *Fig.* 294, shows the principle of the machine invented by Mr. Armstrong, and by which the electrical steam is developed, so as to make the electricity itself available.

The boiler, A, placed over a furnace, is furnished with the safety valve and lever, B. The boiler is of rolled iron, and strong enough to sustain an internal pressure equal, at least, to 100 pounds, to the square inch. Surmounting the boiler, which may be of any capacity from 10 to 100 gallons, is the sheet iron box, C, containing the tubes through which the electrical steam passes. This is attached to the boiler by means of a short tube having the stop-cock, D. This enters into a larger cross tube, E, into which enters the six jet tubes, F, for the escape of the steam.

FIG. 294.



Hydro-Electrical Machine.

These jet tubes are of peculiar construction, and on this depends their efficacy in developing the electrical aura. The lower portion where they are attached to the cross tube, is of brass, and the upper, where the steam escapes, is of wood; it being found that the metal would conduct off the electricity. In some machines these tubes are crooked, and in number 40 or 50.

304. ACTION.—Having half filled the boiler through the tubulure, G, apply the fire with the stop-cock, D, open, so as to drive off the air, then having closed it, when the weight on the safety valve shows a pressure of 80 or 90 pounds to the square inch, open the stop-cock, and let in the steam. As it escapes, it will be found that the tubes and boiler are powerfully negative, while the steam itself is intensely positive. On approaching

a brass ball properly insulated to any of the escape tubes or box, vivid electrical flashes will be seen, displaying a very striking experiment.

When large quantities are required, it is said that this is the best means of obtaining it.

305. Origin.—With respect to the origin of the electricity by steam, it is the theory of Dr. Faraday, that the friction between the steam and the wooden tops of the escape tubes, are its exciting cause, for if the safety valve be opened, and the steam be allowed to escape freely, not a vestage of electricity can be detected.

The box, C, is filled with cold water during the experiment, for it is found that when a portion of the escaping steam is condensed, the electricity is more abundant.

CHAPTER XIV.

MAGNETISM.

306. *The native Magnet or Loadstone, is an ore of iron, which is found in various parts of the world. Its color is iron black; its specific gravity from* 4 *to* 5, *and it is sometimes found in crystals.*

This substance, without any preparation, attracts iron and steel, and when suspended by a string, will turn one of its sides toward the north, and another toward the south.

It appears that an examination of the properties of this species of iron ore, led to the important discovery of the magnetic needle, and subsequently laid the foundation for the science of magnetism; though at the present day magnets are made without this article.

The whole science of magnetism is founded on the fact, that pieces of iron or steel, after being treated in a certain manner, and then suspended, will constantly turn one of their ends toward the north, and consequently the other toward the south. The same property has been more recently proved to belong to the metals, *nickel* and *cobalt*, though with much less intensity.

307. Still more recently, it has been found by Prof. Faraday, that when a strong electro-magnet is employed, the following

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306. What is the native magnet or loadstone? What are the properties of the loadstone? On what is the whole subject of magnetism founded? What other metals besides iron possess the magnetic property? 307. What metals besides iron, nickel, and cobalt, are magnetic?

metals will be acted upon with varying intensity, and therefore must be added to the list of magnetic metals, viz; *manganese*, *chromium*, *cerium*, *titanium*, *palladium*, *platinum*, and *osmium*.

308. The *poles* of a magnet are those parts which possess the greatest power, or in which the magnetic virtue seems to be concentrated. One of the poles points north, and the other south. The *magnetic meridian* is a vertical circle in the heavens, which intersects the horizon at the points to which the magnetic needle, when at rest, directs itself.

309. The *axis* of a magnet, is a right line which passes from one of its poles to the other.

The *equator* of a magnet, is a line perpendicular to its axis, and is at the center between the two poles.

310. *Leading Properties.*—The leading properties of the magnet are the following: It attracts iron and steel, and when suspended so as to move freely, it arranges itself so as to point north and south; this is called the *polarity* of the magnet. When the *south* pole of one magnet is presented to the *north* pole of another, they will attract each other; this is called *magnetic attraction.* But if the two north, or two south poles be brought together, they will repel each other, and this is called *magnetic repulsion.*

311. When a magnet is left to move freely, it does not lie in a horizontal direction, but one pole inclines downward, and consequently the other is elevated above the line of the horizon. This is called the *dipping* or *inclination* of the magnetic needle. Any magnet is capable of communicating its own properties to iron or steel, and this, again, will impart its magnetic virtue to another piece of steel, and so on indefinitely.

312. If a piece of iron or steel be brought near one of the poles of a magnet, they will attract each other, and if suffered to come into contact, will adhere so as to require force to separate them. This attraction is mutual; for the iron attracts the magnet with the same force that the magnet attracts the iron. This may be proved, by placing the iron and magnet on pieces of wood floating on water, when they will be seen to approach each other mutually.

313. *Force of Attraction.*—The force of magnetic attraction varies with the distance in the same ratio as the force of gravity; the attracting force being inversely as the square of the distance between the magnet and the iron.

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308. What are the poles of a magnet? 309. What is the axis of a magnet? What is the equator of a magnet? 310. What is meant by the polarity of a magnet? When do two magnets attract, and when repel each other? 311. What is understood by the dipping of the magnetic needle?

314. The magnetic force is not sensibly affected by the interposition of any substance except those containing iron, or steel. Thus, if two magnets, or a magnet and piece of iron, attract each other with a certain force, this force will be the same if a plate of glass, wood, or paper, be placed between them. Neither will the force be altered, by placing the two attracting bodies under water, or in the exhausted receiver of an air-pump. This proves that the magnetic influence passes equally well through air, glass, wood, paper, water, and a vacuum.

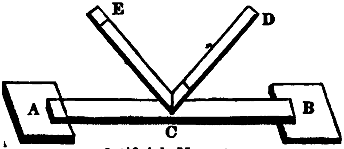
315. *Destroyed by Heat.*—Heat weakens the attractive power of the magnet, and a white heat entirely destroys it. Electricity will change the poles of the magnetic needle, and the explosion of a small quantity of gun-powder on one of the poles will have the same effect.

The attractive power of the magnet may be increased by permitting a piece of steel to adhere to it, and then suspending to the steel a little additional weight every day, for it will sustain, to a certain limit, a little more weight on one day than it would on the day before.

316. Small natural magnets will sustain more than large ones in proportion to their weight. It is rare to find a natural magnet, weighing 20 or 30 grains, which will lift more than thirty or forty times its own weight. But a minute piece of natural magnet, worn by Sir Isaac Newton, in a ring, which weighed only three grains, is said to have been capable of lifting 746 grains, or nearly 250 times its own weight.

317. *Artificial Magnets.*—The magnetic property may be communicated from the loadstone, or artificial magnet, in the following manner, it being understood that the north pole of one of the magnets employed, must always be drawn toward the south pole of the new magnet, and that the south pole of the other magnet employed, is to be drawn in the contrary direction. The north poles of magnetic bars are usually marked with a line across them, so as to distinguish this end from the other. Place two magnetic bars

FIG. 295.



Artificial Magnets.

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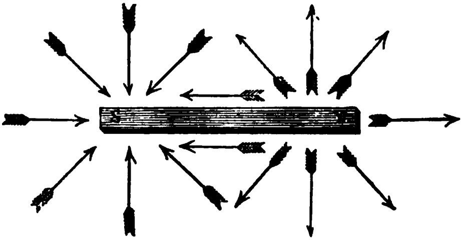
312. How is it proved that the iron attracts the magnet with the same force that the magnet attracts the iron? 313. How does the force of magnetic attraction vary with the distance? 314. Does the magnetic force vary with the interposition of any substance between the attracting bodies? 315. What is the effect of heat on the magnet? What is the effect of electricity, or the explosion of gun-powder on it? How may the power of a magnet be increased? 316. What is said concerning the comparative powers of great and small magnets? 317. Explain Fig. 295. and describe the mode of making magnets.

A and B, *Fig.* 295, so that the north end of one may be nearest the south end of the other, and at such a distance that the ends of the steel bar to be touched, may rest upon them. Having thus arranged them, as shown in the figure, take the two magnetic bars, D and E, and apply the south end of E, and the north end of D, to the middle of the bar, C, elevating their ends as seen in the figure. Next separate the bars, E and D, by drawing them in opposite directions along the surface of C, still preserving the elevation of their ends; then removing the bars, D and E, to the distance of a foot or more from the bar, C, bring their north and south poles into contact, and then having again placed them on the middle, C, draw them in contrary directions, as before. The same process must be repeated many times on each side of the bar, C, when it will be found to have acquired a strong and permanent magnetism.

318. If a bar of iron be placed, for a long period of time, in a north and south direction, or in a perpendicular position, it will often acquire a strong magnetic power. Old tongs, pokers, and fire shovels, almost always possess more or less magnetic virtue; and the same is found to be the case with the iron window bars of ancient houses, whenever they have happened to be placed in the direction of the magnetic line.

FIG. 296.



Magnetic Rotation.

319. A *magnetic needle*, such as is employed in the mariner's and surveyor's compass, may be made by fixing a piece of steel on a board, and then, drawing two magnets from the center toward each end, as directed at *Fig.* 295. Some magnetic needles, in time, lose their virtue, and require again to be magnetized. This may be done by placing the needle still suspend-

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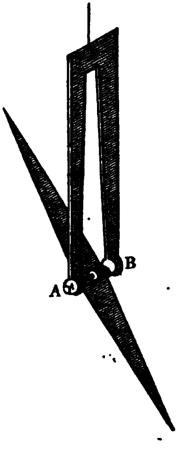
318. In what positions do bars of iron become magnetic spontaneously? **319.** How may a needle be magnetized without removing from its pivot?

ed on its pivot, between the opposite poles of two magnetic bars. While it is receiving the magnetism, it will be agitated, moving backward and forward, as though it were animated; but when it has become perfectly magnetized, it will remain quiescent.

320. *Magnetic Rotation.*—It is quite interesting to observe the different directions the needle of a small magnetic compass will assume when moved round a bar magnet. If the latter be laid on the table, and the former carried slowly around it, from S, or south, to N, or north, and so back again on the other side, the needle will alternately take all the positions shown by *Fig.* 296.

321. DIP OF THE MAGNET.—The *dip* or *inclination* of the magnetic needle, is its deviation from its horizontal position, as already mentioned. A piece of steel, or a needle which will rest on its center, in a direction parallel to the horizon, before it is magnetized, will afterward incline one of its ends toward the Earth. This property of the magnetic needle was discovered by a compass-maker, who, having finished his needles before they were magnetized, found that immediately afterward, their north ends inclined toward the Earth, so that he was obliged to add small weights to their south poles, in order to make them balance as before.

FIG. 297.



Dipping Needle.

322. *Dipping Needle.*—*Fig.* 297 is said to represent a convenient form of the dipping needle. It is a strongly magnetized steel needle, turning on the center of gravity, A B, in a brass frame which is suspended by a thread. Thus the needle has universal motion. The scale is omitted as unnecessary for the present purpose.

323. The dip of the needle does not vary materially at the same place, but differs in different latitudes, increasing as it is carried toward the north, and diminishing as it is carried toward the south. At London, the dip for many years has varied little from 72 degrees. In the latitude of 80 degrees north, the dip, according to the observations of Captain Parry was 88 degrees.

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321. How was the dip of the magnetic needle first discovered? 323. What circumstance increases or diminishes the dip of the needle?

324. Variation of the Magnet.—Although, in general terms, the magnetic needle is said to point north and south, yet this is very seldom strictly true, there being a variation in its direction, which differs in degree at different times and places. This is called the *variation*, or *declination*, of the magnetic needle.

325. This variation is determined at sea, by observing the different points of the compass at which the Sun rises, or sets, and comparing them with the true points of the Sun's rising or setting, according to astronomical tables. By such observations it has been ascertained that the magnetic needle is continually declining alternately to the east or west from due north, and that this variation differs in different parts of the world at the same time and at the same place at different times.

326. The annexed table shows at once, the *dip*, or *inclination*, and the *variation* or *declination* of the needle, for a series of years. It was formed from observations made at Brussels, and by it there appears to be a gradual but constant diminution of the angle, both of *inclination* and *declination*, in Europe.

Month.	Year.	Inclination.	Declination.
October, . .	1827,	68°, 56′, 5″	22°, 28′, 8″
March, . . .	1830,	68°, 52′, 6″	22°, 25′, 3″
March, . .	1832,	68°, 49′, 1″	22°, 19′, 0″
March, . . .	1833,	68°, 42′, 8″	22°, 13′, 4″
April, . .	1834,	68°, 38′, 4″	22°, 15′, 2″
March, . . .	1835,	68°, 35′, 0″	22°, 6′, 7″
March, . .	1836,	68°, 32′, 2″	22°, 7′, 6″
March, . . .	1837,	68°, 28′, 8″	22°, 4′, 3″
March, . .	1838,	68°, 26′, 1″	22°, 3′, 7″
March, . . .	1839,	68°, 22′, 4″	21°, 53′, 6″

327. The difference in the declination, which may be of much importance, as on it may depend the safety of ships at sea, is very material in different countries, and at different periods. Thus at present it is about 24° west at London. At Paris, 22° west. At New York, 5° 25′ west, and at Hartford, about 6° west.

Before 1660, the variation at London was toward the east, and on that year the needle pointed due north. From that time to the present, it has gained from two to six degrees toward the west every year.

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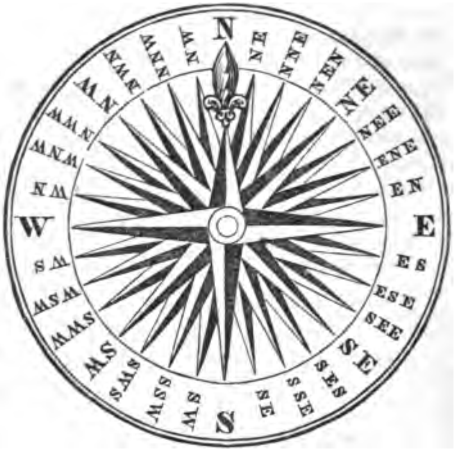
324. What is meant by the declination of the magnetic needle? 326. What changes does the above table indicate? 327. Why is the difference of declination of importance to ships?

The greatest variation of the magnetic needle, recorded, was that observed by Capt. Cook, which was about 43° west. This was in S. latitude, 60°, and E. longitude, 92° 36′.

MARINERS' COMPASS.

328. The face of the most important of all nautical instruments, the Mariners' Compass, is represented by *Fig.* 298. The magnetic needle is placed *under* the card on which are printed the 32 points of the compass, with the letters by which each point is designated, so that nothing is seen of the means by which the face is kept in its proper direction. The face is fitted up with two sets of axes, so as to retain its horizontal position as the vessel rolls.

FIG. 298.



Mariners' Compass.

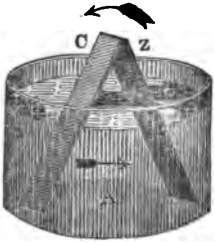
CHAPTER XV.

ELECTRO-MAGNETISM.

329. *When two metals, one of which is more easily oxydated than the other, are placed in acidulated water, and the two*

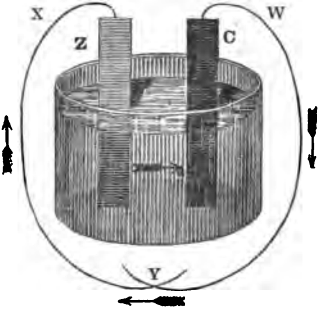
metals are made to touch each other, or a metallic communication is made between them, there is excited an electrical or galvanic current, which passes from the metal most easily oxydated, through the water, to the other metal, and from the other metal through the water around to the first metal again, and so in a perpetual circuit.

FIG. 299.



Galvanic Current.

FIG. 300.



Galvanic Battery.

330. If we take, for example, one slip of zinc, and another of copper, and place them in a cup of diluted sulphuric acid, *Fig.* 299, their upper ends in contact and above the water, and their lower ends separated, then there will be constituted a *galvanic circle*, of the simplest form, consisting of three elements, *zinc*, *acid*, *copper*. The galvanic influence being excited by the acid, will pass from the zinc, Z, the metal most easily oxydated, through the acid, to the copper, C, and from the copper to the zinc again, and so on continually, until one or the other of the elements is destroyed, or ceases to act.

The same effect will be produced, if instead of allowing the metallic plates to come in contact, a communication between them be made by means of wires, as shown by *Fig.* 300. In this case, as well as in the former, the electricity proceeds from the zinc, Z, which is the positive side, to the copper, C, being conducted by the wires in the direction shown by the arrows.

The completion of the circuit by means of wires enables us to make experiments on different substances by passing the galvanic influence through them, this being the method employed to exhibit the effects of galvanic batteries, and by which the most intense heat may be produced.

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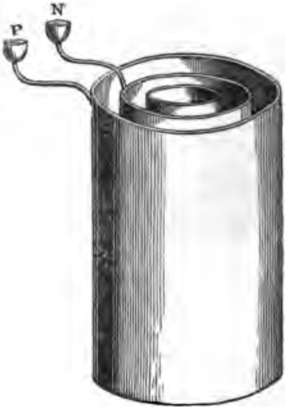
329. What conditions are necessary to excite the galvanic action? From which metal does the galvanism proceed? 330. Describe the circuit by Fig. 299.

When the two poles of a battery are connected by means of a copper wire of a yard or two in length, the two parts being supported on a table in a north and south direction, for some of the experiments, but in others the direction must be changed as will be seen. This wire, it will be remembered, is called the *uniting wire.*

FIG. 301.



Galvanic Battery.

331. *Theory.*—In theory, the positive electricity is produced by the mutual action of the acid, water, and zinc; the water, in small quantity, being decomposed. If this action is too violent, that is, if the acid is too strong and the hydrogen produced in too large quantity, the electrical current is diminished, or ceases almost entirely.

332. GALVANIC BATTERY.—One of the most convenient forms of a galvanic battery for experiments described in this work, is represented by *Fig.* 301. It consists of a cylinder of sheet copper, within which is another of zinc. The zinc has for its bottom a piece of sheep-skin, or bladder, tied on with a string, and is suspended an inch or two from the bottom of the copper cylinder. Or, the whole inner cylinder may be made of leather with a slip of zinc within it. This is done to prevent the fluid which the inner cylinder contains from mixing with that contained between the two; and still, the leather being porous, the water it contains conducts the galvanic influence from one cell to the other, as already stated. The diameter of the outer cup may be five or six inches, and the inner one three or four. The zinc may be suspended by making two holes near the top and tying on a piece of glass tube or a slip of wood. This part has often to be removed and cleaned, by scraping off the black oxyd, which, if it remains, will prevent the action of the battery. The action will be sustained much longer if the zinc is amalgamated by spreading on it a little mercury before it is used, and while the surface is bright.

The cups, P N, are positive and negative poles. They may

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331. How is positive electricity produced? 332. Explain Fig. 301, and show the action of the battery.

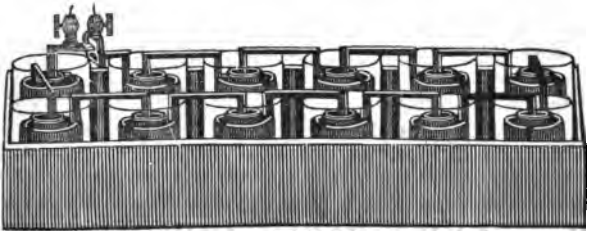
be made of percussion caps, soldered to the ends of two copper wires; the other ends being connected by soldering, or otherwise, one with the zinc, and the other with the copper cylinder.

The inner cup is to be filled with water, mixed with about a twentieth part of sulphuric acid, while the cell between the two contains a saturated solution of sulphate of copper, or blue vitrol. In order to keep the solution saturated, especially when casts are to be taken, some of the solid vitrol is to be tied in a rag, and suspended in it.

GROVE'S BATTERY.

333. This is the most powerful arrangement, according to its size and cost, which has been proposed, and is that generally used for telegraphic purposes. *Fig.* 302, shows a battery of twelve cups, each of which consists of a cylinder of amalgamated zinc, within which is a cup of unglazed clay; these being placed within an outer cup of glass. To the zinc is attached a conducting arm of the same metal, which reaches to the next series of cups, and at the end of which is attached a thin piece of platina, which dips into the porous cup, as shown by the figure.

FIG. 302.



Grove's Twelve-Cup Battery.

The battery is charged, by filling the clay cup with nitric acid, and the space within and around the zinc, which is open at the bottom and side, with sulphuric acid, diluted with 30 parts of water. The action is strong, and requires very little expense.

THE CHESTER BATTERY.—This battery, the recent invention of Mr. Chester, of New York, is on the same principle as Grove's Battery, but experiment shows that it is much more economical, and requires much less care to keep it in order. It also is, much more durable than Grove's.

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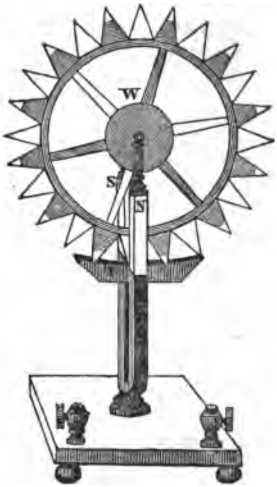
333. Describe the principle of Grove's battery, Fig. 302.

334. **Revolving Spur-Wheel.**—Many curious experiments are made by combining the action of electricity with that of magnetism. Such a combination is shown by *Fig.* 303, where W is a copper wheel cut into points, and made to revolve between the legs of a U magnet fixed in an upright position. The axis of the wheel is supported by strips of brass fastened to the magnetic poles, N and S. The trough, T, may be of brass or wood, and is placed between the bifurcation of the magnet. This contains a little mercury, into which the teeth of the wheel just dip, as they revolve.

FIG. 303.



Revolving Wheel.

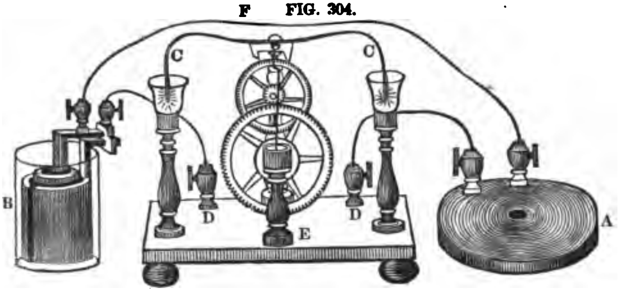
335. On the platform or stand, to which the magnet is fastened, are two screw-cups to which the opposite poles of the battery are fastened. One of these cups is connected with the magnet, and through that, with the axis of the wheel, and the other with the mercury in the trough. Now on making the connection between the poles of the battery, the wheel begins to move, in consequence of the attraction between the points of the wheel and the mercury, and if the current is strong the wheel turns with great velocity, snapping and striking fire as the points approach the fluid metal. The points of the wheel should be amalgamated to make the experiment succeed well.

CLOCK-WORK VIBRATING WIRE.

336. This is a curious and singular arrangement, and will quite astonish those who are not conversant with motions communicated by galvanic influence.

The cut, *Fig.* 304, shows a connection between the *spiral ribbon*, A, and the single Grove's battery, B, by means of a copper wire. The bent wire, C C, suspended in the middle, is set in motion by a spring below the milled-head, F, and is made to vibrate rapidly by clock-work, the ends of the wire dipping alternately in the glass cups, C C, containing mercury. The spring is wound up by turning the milled-head.

FIG. 304.



Clock-work Vibrating Wire.

The glass cups are open at the bottom to allow the mercury to come in contact with the brass pillars on which they stand.

Both of these pillars are connected with one of the screw-cups, D D, while the other cup is connected with the middle brass pillar, E, on which is a brass cup of mercury. From the latter cup ascends a vertical wire, attached to the vibrating wire, as the figure shows.

337. Such a quantity of mercury is put into the brass cup as to keep the end of the vertical wire covered, and enough into the glass cups, C C, to allow one end of the vibrating wire to leave the mercury in the cup, before the other end dips into that metal.

338. The *spiral ribbon* is made by cutting strips of sheet copper, an inch wide, into lengths, and soldering them together. Then having covered the whole with cotton cloth, and rolled it into a spiral, like a watch-spring, the article in question is formed. At each end, the ribbon being sometimes 100 feet long, there is fixed a screw-cup to contain mercury for the poles of the battery. In the above, one end is connected with the battery, and the other with the screw-cup, D, and so to E, on the platform.

The current must be transmitted through the two instruments in succession, by connecting one of the screw-cups with one of those attached to the spiral wire, and the other with the pole of the battery; the remaining cup on the spiral being made to communicate with the other pole of the battery.

339. *Action.*—On making the connection with the spiral, as shown, and turning the milled-head to put the vibrating wire in motion, a brilliant spark will be seen, and a loud snap

heard, at the alternate rupture of the contact between the ends of the wire and the mercury in the cups, C C.

With a battery of a few pairs of large sized plates, the size of the spark will be greatly increased.

A strong shock may also be given, especially when the mercury in the cups, C C, are covered with a little oil.

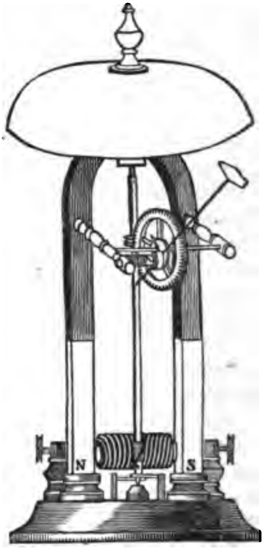
[The author is indebted for the above, as well as for several other cuts of the same kind, to Davis's "Manual of Magnetism," Boston, 1850.

This work contains the most complete and extensive set of figures, and their descriptions, on the subjects of Magnetism and Electricity, ever published in this country. Price $1,00. The number of figures, 184.]

REVOLVING BELL ENGINE.

340. This curious arrangement is the invention of Mr. Page. It consists of a U shaped magnet, the north and south poles, N S, being fixed in the base board. Between these is a small electro-magnet of iron, surrounded with insulated copper wire. This is fixed to a revolving axis, or wire, the upper end of which is confined in the bend of the large magnet, and the lower one running in a support below the electro-magnet. On the outside of the U magnet are the connecting screws for the opposite poles of the battery, by which the machine is operated. On the axis, and connected with the notches of the wheel, is an endless screw, and with this is connected the hammer, which strikes the bell, seen as a crown on the figure.

FIG. 305.



Bell Engine.

341. *Action.*—The operation, or motion, of this curious little engine, depends on the alternate attraction and repulsion of the poles of the U magnet, and those of the small electro-magnet between them. The magnetism of the

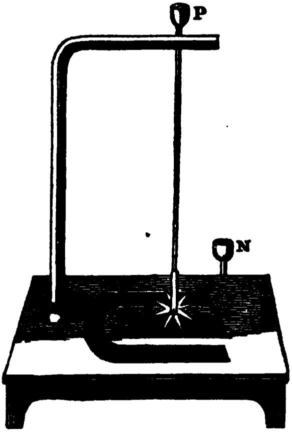
latter depends on the influence of the battery with which it is connected, and therefore ceases when this connection is broken. The revolution is therefore caused by the mutual repulsion, and then the mutual attraction between the two opposite poles of the two magnets, as the connection is broken and the poles of the electro-magnet are reversed.

The hammer is made to strike by a pin on the wheel, moved by the endless screw, and which presses back the handle, until it is released, when a spiral spring on the handle impels it against the bell.

342. If the wheel has 100 teeth, as in the cut, the electro-magnet must revolve 100 times in order to produce one revolution of the wheel, and consequently one stroke on the bell. The velocity of the electro-magnet in this machine, as shown by the striking of the hammer, is sometimes equal to 6000 revolutions in a minute.

343. ROTATION OF A WHEEL, *similar to, but more simple, than Fig.* 303. The same force which throws the wire away from the mercury, will cause the rotation of a spur-wheel. For this purpose the conducting wire, instead of being suspended, as in the former experiment, must be fixed firmly to the arm, as shown by *Fig.* 306. A support for the axis of the wheel may be made by soldering a short piece to the side of the conducting wire, so as to make the form of a fork, the lower end of which must be flattened with a hammer, and pierced with fine orifices, to receive the ends of the axis.

FIG. 306.



Rotation of a Wheel.

The apparatus for a revolving-wheel is, in every respect, like that already described for the vibrating wire, except in that above noticed, the wheel may be made of brass or copper, but must be thin and light, and so suspended as to move freely and easily. The points of the notches must be amalgamated, which is done in a few minutes, by placing the wheel on a flat surface, and

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343. Explain Fig. 306. In what manner may the points of the spur-wheel be amalgamated? If the motion of the fluid is changed, what effect does it have on the wheel?

rubbing them with mercury by means of a cork. A little diluted acid from the galvanic battery will facilitate the process. The wheel may be from half an inch to several inches in diameter. A cent hammered thin, which may be done by heating it two or three times during the process, and then made perfectly round, and its diameter cut into notches with a file, will answer every purpose.

This affords a striking and novel experiment; for when every thing is properly adjusted, the wheel instantly begins to revolve on touching with one of the wires of the battery the mercury in the cup, P, the other pole being in N.

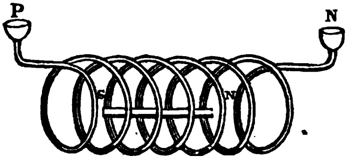
When the poles of the magnet, or those of the battery, are changed, the wheel instantly revolves in a contrary direction from what it did before.

It is, however, not absolutely necessary to divide the wheel into notches, or rays, in order to make it revolve, though the motion is more rapid, and the experiment succeeds much better by doing so.

344. ELECTRO-MAGNETIC INDUCTION.—*Experiment proves that the passage of the galvanic current through a copper wire renders iron magnetic when in the vicinity of the current. This is called magnetic induction.*

The apparatus for this purpose is represented by *Fig.* 307, and consists of a copper wire coiled, by winding it around a piece of wood. The turns of the wire should be close together for actual experiment, they being parted in the figure to show the place of the iron to be magnetized. The best method is, to place the coiled wire, which is called an *electrical helix*, in a glass tube, the two ends of the wire, of course, projecting. Then placing the body to be magnetised within the folds, send the galvanic influence through the whole by placing the poles of the battery in the cups.

FIG. 307.



Electrical Helix.

345. Steel thus becomes permanently magnetic, the poles, however, changing as often as the fluid is sent through it in a contrary direction. A piece of watch-spring placed in the helix,

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344. What is meant by magnetic induction? Explain Fig. 307. What is the figure called? 345. Does any substance become permanently magnetic by the electrical helix? How may the poles of a magnet be changed by the helix?

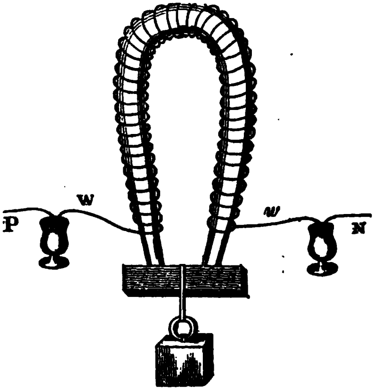
and then suspended, will exhibit polarity, but if its position be reversed in the helix, and the current again sent through it, the north poles will become south. If one blade of a knife be put into one end of the helix, it will repel the north pole of a magnetic needle, and attract the south; and if the other blade be placed in the opposite end of the helix, it will attract the north pole, and repel the south, of the needle.

346. Temporary Magnets.—*Temporary magnets, of almost any power, may be made by winding a thick piece of soft iron with many coils of insulated copper wire, and passing the galvanic influence through it.*

The best form of a magnet for this purpose is that of a horseshoe, and which may be made in a few minutes by heating and bending a piece of cylinder iron, an inch or two in diameter, into this form.

The copper wire (bell wire) may be insulated by winding it with cotton thread. If this can not be procured, common bonnet wire will do, though it makes less powerful magnets than copper.

FIG. 308.



Temporary Magnet.

347. The coils of wire may begin near one pole of the magnet and terminate near the other, as represented by *Fig.* 308, or the wire may consist of shorter pieces wound over each other, on any part of the magnet. In either case, the ends of the wire, where several pieces are used, must be soldered to two strips of tinned sheet copper, for the combined positive and negative poles of the wires. To form the magnet, these pieces of copper are made to communicate with the poles of the battery, by means of cups containing mercury, as shown in the figure, or by any other method.

348. The effect is surprising, for on completing the circuit with a piece of iron an inch in diameter, in the proper form,

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346. How may temporary magnets be made? 347. For what purpose are the ends of the wires to be soldered to pieces of copper? 348. What is meant by thermo-electricity?

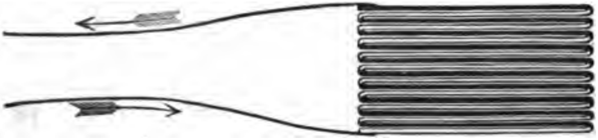
and properly wound, a man will find it difficult to pull off the armature from the poles; but on displacing one of the galvanic poles, the attraction ceases instantly, and the man, if not careful, will fall backward, taking the armature with him. Magnets have been constructed in this manner, which would suspend ten thousand pounds.

THERMO-ELECTRICITY.

349. This means electricity by heat, and its principles will be understood, when it is stated that if any two metals of different kinds be joined together and then heated, a current of electricity will pass from one to the other. Thus, if two wires of a few inches in length, German-silver, and brass, have their ends soldered together, and the junction heated with an alcohol lamp, or by other means, a current of electricity will flow from the silver to the brass, which may be detected by the galvanometer, or by the common electrical needle.

350. *Composition of German-silver.*—As this alloy is cheap, and is much used for electrical purposes, we give its proportions. In 100 parts, it consists of copper 50, zinc 30, and nickel 20. This alloy is a positive electric to all other metals except bismuth, to which it is negative.

FIG. 309.



Thermo-Electricity.

Writers give a great variety of combinations of different metals, with the amount of electrical influence indicated by each. Among these, that shown by *Fig.* 309, is among the most easily constructed and most powerful. It consists of ten strips of German-silver, and as many of brass, rolled thin and laid on each other with their alternate ends soldered together. Strips of pasteboard are placed between the adjacent metals, so that they touch only at the ends where they are soldered. Now by heating the end opposite the poles with a spirit lamp, and bring-

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349. Explain by Fig. 309, how thermo-electricity is developed. 350. What is electrotype? On what fact is it said this art is founded? On which pole is the metal deposited? What is the theory by which this effect is explained?

ing the poles in contact, an electrical current will flow from one side or pole, to the other, in the direction of the arrows.

ELECTROTYPE.

351. The art of covering the base metals, as copper, and the alloys of zinc, tin, &c., with gold and silver, as also of copying medals, by means of the electrical current, is called *electrotype* or *voltatype.*

This new art is founded on the simple fact, that when the galvanic influence is passed through a metallic solution, under certain conditions, decomposition takes place, and the metal is deposited in its pure form on the negative pole of the battery.

The theory by which this effect is explained is, that the hydrogen evolved by the action of the acid on the positive pole of the battery, combines with the oxygen of the dissolved metal forming water, while the metal itself thus set free, is deposited at the negative side of the battery.

Many of the base metals, as copper, the alloys of zinc, and tin, may by such means be covered with gold, or silver, and thus a cheap and easy method of gilding and plating is effected.

352. Copying of Medals.—This new art has been applied very extensively in the copying of ancient coins and medals, which it does in the utmost perfection, giving every letter, and feature, and even an accidental scratch, exactly like the original. When the coin is a *cameo*, the figures or letters being raised, it is obvious that if the metal be cast directly upon it, the medal will be reversed, that is, the figures will be indented, and the copy will be an *intaglio* instead of a cameo. To remedy this, a cast, or impression must first be taken of the medal, on which the electrotype process is to act, when the copy will, in all respects, imitate the original.

There is a variety of ways of making such casts, according to the substance used for the purpose. We shall only mention plaster of Paris, wax, and fusible metal.

353. Plaster Casts.—When plaster is used, it must be, what is termed baked, that is, heated, so as to deprive it of all moisture. This is the preparation of which stereotype casts are made. The dry powder being mixed with water to the consistence of cream, is placed on the medal with a knife to the thickness of a quarter or half an inch, according to its size. In a few minutes the plaster *sets*, as it is termed, or becomes hard. To insure its easy detachment, the medal is rubbed over with a little oil.

The cast thus formed is first to be coated with boiled linseed oil, and then its face covered with fine pulverized black lead, taking care that the indented parts are not filled, nor the raised parts left naked. The lead answers the purpose of a metallic surface, on which the copper is deposited by the galvanic current. This is a curious and very convenient discovery, since wood cuts, engraved stones, and copies in sealing-wax, can thus be copied.

To insure contact between the black lead on the face of the cast and the wire-conductor, the cast is to be pierced with an awl, on one of its edges, and the sharp point of the wire passed to the face, taking care, after this is done. to rub on more lead, so that it shall touch the point of the wire, and thus communicate with the whole face of the medal.

354. Wax Casts.—To copy medallions of plaster of Paris, place the cast in warm water, so that the whole may be saturated with the water, but keeping the face above it. When the cast has become warm and moist, remove, and having put a slip of paper around its rim, immediately pour into the cup thus formed bees wax, ready melted for this purpose. In this way copies may be taken, not only from plaster casts, but from those of other substances.

To render the surface of the wax a conductor of electricity, it is to be covered with black lead in the manner directed for plaster casts. This is put on with a soft brush, until it becomes black and shining.

The electrical conductor is now to be heated and pressed upon the edge of the wax, taking care that a little of its surface is left naked, on, and around which the black lead is again to be rubbed, to insure contact with the whole surface.

Both of the above preparations require considerable ingenuity and attention, in order to make them succeed in receiving the copper. If the black lead does not communicate with the pole, and does not entirely cover the surface, or if it happens to be a poor quality, which is common, the process will not succeed; but patience, and repeated trials, with attention to the above descriptions, will insure final success.

355. Fusible Metal Casts.—This alloy is composed of 8 parts of bismuth, 5 of lead, and 3 of tin, melted together. It melts at about the heat of boiling water, and hence may be used in taking casts from engraved stones, coins, or such other substances as a small degree of heat will not injure.

To take a cast with this alloy, surround the edge of the medal to be copied, with a slip of paper, by means of paste, so as to form a shallow cup, the medal being the bottom. Then having melted the alloy in a spoon, over an alcohol lamp, pour it in, giving it a sudden blow on the table, or a shake, in order to detach any air, which may adhere to the medal. In a minute or two it will be cool, and ready for the process.

Another method is, to attach the medal to a stick, with sealing-wax, and having poured a proper quantity of the fused alloy on a smooth board, and drawn the edge of a card over it, to take off the dross, place the medal on it, and with a steady hand let it remain until the cast cools.

Next, having the end of the copper wire for the zinc pole clean, heat it over a lamp, and touch the edge of the cast therewith, so that they shall adhere, and the cast will now be ready for the galvanic current.

To those who have had no experience in the electrotype art, this is much the best and most easy method of taking copies, as it is not liable to failure like those requiring the surfaces of the moulds to be black leaded, as above described.

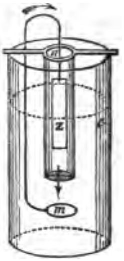
356. Galvanic Arrangement.—Having prepared the moulds, as above directed, these are next to be placed in a solution of the sulphate of copper, (blue vitrol) and subjected to the electrical current. For this purpose only a very simple battery is required,* especially where the object is merely a matter of curiosity.

For small experiments, a glass jar holding a pint, or a pitcher, or even a tumbler will answer, to hold the solution. Provide also a cylinder of glass, two inches in diameter, and stop the bottom with some moist plaster of Paris, or instead thereof, tie around it a piece of bladder, or thin leather, or the whole cylinder may be made of leather, with the edges sewed nicely together, and stopped with a cork, so that it will not leak. The object of this part of the arrangement is, to keep the dilute sulphuric acid which this contains, from mixing with the solution of sulphate of copper, which surrounds it, still having the texture of this vessel so spongy as to allow the galvanic current to pass through the moisture which it absorbs, water being a good conductor of electricity.

Provide also a piece of zinc in form of a bar or cylinder, or slip, of such size as to pass freely into the above described cylinder.

Having now the materials, the arrangement will readily be understood by *Fig.* 310, where C is the vessel containing the solution of sulphate of copper; A, the cylinder of leather, or glass; Z, the zinc, to which a piece of copper wire is fastened, and at the other end of which, is the cast, M, to be

FIG. 310.



copied. The proportions for the vessel, A, are about 1 part sulphuric acid to 16 of water by measure. The solution of copper for C, may be in the proportions of 2 ounces of the salt to 4 ounces of water. The voltaic current passes from the positive zinc to the negative amalgam cast, where the pure copper is deposited.

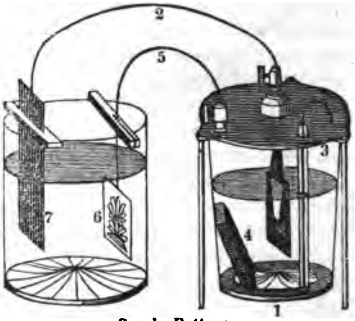
In order to keep the solution saturated, a little sulphate of copper is tied in a rag, and suspended in the solution. In 24 or 36 hours, the copper, (if all is right,) will be sufficiently thick on the cast, the back and edges of which should be covered with varnish to prevent its deposition except on the face.

If the copper covers the edges, a file or knife will remove it, when by inserting the edge of the knife between the two metals, the copy will be separated, and will be found an exact copy of the original.

If the acid in the inner cylinder is too strong, the process is often too vigorous, and the deposition, instead of being a film of solid copper on the cast, will be in the form of small grains on the lower end of the wire. The weakest power consistent with precipitation should therefore be applied.

SMEE'S BATTERY.

FIG. 311.



Smee's Battery.

357. This is an improved method of copying casts, or moulds, in copper. It consists of two glass vessels, each holding a pint, or less, one of which holds the battery, and the other the depositing apparatus. These arrangements will be understood by *Fig.* 311, of which 1 is a little mercury on the bottom of the vessel, containing the battery. Just above this is a piece of platinum foil, suspended in the center. A piece of zinc, 4, rests against the side of the vessel. A curved copper wire, 3, descends through the liquid, insulated by a glass tube. This wire, by the mercury, connects the zinc plate with

the metallic cup on the top of the jar, and by the wire, 2, with the other jar. The wire, 5, descends from the screw-cup into the depositing cell, to the end of which the cast, 6, is suspended. The plate, 7, is a piece of copper suspended in the solution of sulphate of copper, in order to keep it always of the same strength, a portion being dissolved, while another portion is deposited on the cast.

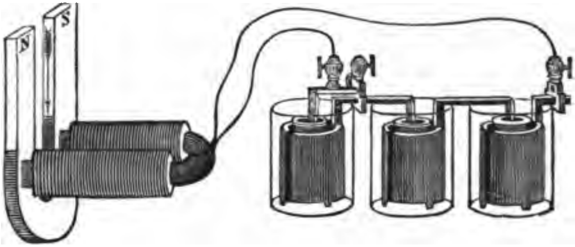
The liquid in the battery is composed of one part sulphuric acid, and 20 or 30 of water. That in the depositing side, is composed of 2 ounces of sulphate of copper, 1 ounce of sulphuric acid, and 15 ounces of water.

The general directions for obtaining casts have been given above, and need not be repeated.

MAGNETISM BY ELECTRO-MAGNETISM.

358. The apparatus, *Fig.* 312, is designed to communicate strong and permanent magnetism to steel. It consists of a small Smee's battery, with its opposite poles connected with the horizontal U magnet, which is closely wound with insulated copper wire. Of course the wires convey the electrical influence from the positive to the negative sides of the battery.

FIG. 312.



Magnetism by Electro-Magnetism.

The cut represents a U magnet in the process of being magnetized. This is done by drawing it from the bend, across the electro-magnet to the poles, and repeating this on both its sides, taking care to do it in the same direction. A steel bar may be magnetized by the same process, or, if a short one, by applying it as an armature to the poles of the electro-magnet; the north pole becoming the south pole of the new magnet.

359. To remove the magnetism of a steel magnet of the U form, it is only required to reverse the process, that is, to place

one of its poles on each pole of the electro-magnet, and draw it over them, in the direction contrary to the indication of the arrow seen in the figure.

In the vertical magnet, the letters, N S, indicate its north and south poles.

ELECTRO—GILDING.

360. *Gilding without a Battery.*—After the solution is prepared, the process of electrotype-gilding is quite simple, and may be performed by any one of common ingenuity.

The solution for this purpose is cyanide of gold dissolved in pure water. This is prepared by dissolving the metal in aqua-regia, composed of one part nitric, and two of muriatic acid. Ten or fifteen grains of gold, to an ounce and a half of the aqua-regia may be the proportions. The acid being evaporated, the salt which is called the chloride of gold is dissolved in a solution, made by mixing an ounce of the cyanuret of potash with a pint of pure water. The cyanuret of potash is decomposed and a cyanide of gold remains in solution. About 20 grains of the chloride of gold is a proper quantity for a pint of the solution. The cyanuret of potash, and the chloride, or oxyd of gold, may be bought at the apothecaries.

Having prepared the solution, the most simple method of gilding is to pour a quantity of it into a glass jar, or a tumbler, and place in it the silver, copper, or German-silver to be gilded, in contact with a piece of bright zinc, and the process will immediately begin. No other battery, except that formed by the zinc, and metal, which receives the gold, is required. The zinc at the point of contact must be bright and well fastened to the other metal, by a string, or otherwise. The process will be hastened by warmth, which may be applied by placing the jar and its contents in a vessel of warm water. So far as the author knows, this simple process originated with himself, and answers admirably as an experiment in the electrotype art. The gold, however, is apt to settle upon the zinc, but which may be prevented by a little shellac varnish rubbed on it, except at the point of contact. The handles of scissors, silver spectacles, pencils, &c., may be handsomely gilt by this process.

361. GILDING WITH A BATTERY.—If the operator desires to extend his experiments in the art of electro-gilding, a small battery must be employed, of which there are many varieties. The best for more extensive operations, is that composed of platinized silver, and amalgamated zinc.

For this purpose the platina is first dissolved in aqua-regia, in proportion of 10 grains to the ounce, and then precipitated on the silver. The silver is in sheets, such as is used for plating, no thicker than thin writing paper. This may be obtained of the silver platers, and being well cleaned, is ready for the process.

These plates being covered with platina, are insoluble in the acid employed, and hence they will last many years. The amalgamated plates are also durable, and do not require cleaning.

362. These platinized sheets are confined between two plates of amalgamated zinc. The process of amalgamation consists in rubbing mercury, with a little mass of cotton wool held in the fingers, on the clean zinc. These plates may be fixed half an inch apart by means of little pieces of wood, with the sheets between them, but not touching each other. The plates, having a metallic connection, form the positive side of the battery, while a copper wire soldered to the silver sheets makes the negative side. The dimensions of these plates may be four or five inches long, and three or four wide.

For experimental purposes, however, a less expensive battery may be used, that represented by *Fig.* 310, made of copper and zinc, being sufficient.

To gild by means of a battery, place the solution, made as above described, in a glass vessel, and connect the article to be gilded with the pole coming from the zinc side of the battery, letting the other wire, which should be tipped with a little piece of gold, dip into the solution. The gilding process will immediately begin, and in three or four hours a good coat of gold will be deposited on the article immersed.

To keep the solution quite pure, the tips of the poles where they dip into the fluid should be of gold. If they are of copper, a portion of the metal will be dissolved and injure the result.

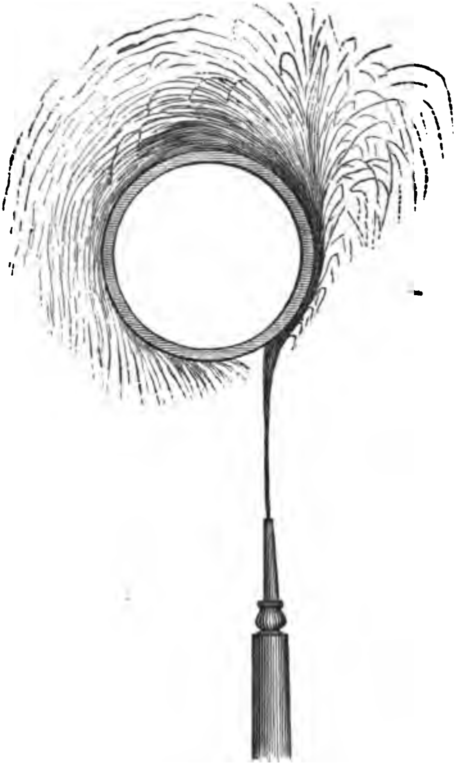
HYDRODYNAMIC EXPERIMNET.

Description.—This, *Fig.* 313, represents the curious and striking effect of a small jet of water in suspending a cork ring in the open air. In the instance to be described, the source of the jet is about fourteen feet above the level of the fountain.

The iron tube leading to the jet, is about six feet high, and the aperture of the jet-tube, the tenth of an inch across, above which the stream rises to the height of four or five feet.

The rings are of cork, and may be from two to three inches in diameter, the thickness of the material being about the fourth of an inch, and the external or outside surface being convex, and in width, half an inch or less.

FIG. 313.



Jet and revolving ring.

Having set the jet in motion, the ring is taken between the thumb and finger, and holding it upright, the external circumference is made to touch the jet, six or eight inches above the tube, when the hand being withdrawn, the ring will remain suspended on the side of the stream, revolving with intense velocity, so as to throw the spray ten or fifteen feet in each direction, as indicated by the figure.

The rings used, are severally 2¼, 2½, and 3½ inches in external diameter, the last being the largest we have succeeded in suspending, though we doubt not much larger ones might be made to succeed on larger and more powerful jets. The rings are painted of various prismatic colors, so that when revolving, they resolve these several colors into one, thus affording quite a curious and striking chromatic experiment, very wonderful and gratifying to those who are unused to such exhibitions.

When the air is still, the ring will remain in its place for any length of time, as from evening till morning, or during twenty-four hours, as we have often witnessed. It is obvious that a slight wind will insure its fall, by forcing the jet out of the vertical direction.

The question, by what counteracting forces this phenomenon, so striking and interesting to every beholder, is explained, remains to be demonstrated by those who are acquainted with the laws of dynamics.

The principle by which these rings are suspended, is obviously quite different from that by which balls are raised by jets of water. If any one will send the author a popular demonstration of it, the next edition shall contain the same. The author does not claim this experiment as his invention, though he has never seen it except at his own fountain.

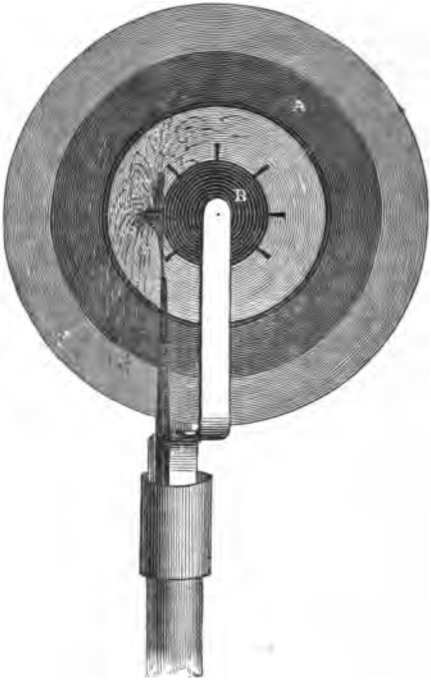
DESCRIPTION OF A WHEEL TURNED BY THE UPWARD FORCE OF A HYDRAULIC JET.

The annexed figure represents a wheel turned by the same force by which the rings are made to revolve, already described in the foregoing page, *Fig.* 313.

This little machine consists of two wheels, A and B, running on the same axis, supported by slips of sheet brass, fixed to a socket, which fits the end of the iron tube conveying the water, and from which also arises the jet-tube, the tenth of an inch in diameter, as seen in the figure. The axis is of wood, about five inches long, terminated at each end by pieces of brass or iron wire, driven into the wood, and on which the machine turns.

The two wheels are about two inches apart, so that the water, as it acts on the one, may not interfere with the other. The small wheel, B, which is the water-wheel, is two and a half inches in diameter. The buckets, eight in number, are made of common tin, a little hollowed on the lower side, and are, in length, about three-quarters of an inch. The action of the jet on the under side of these, forms the force by which the machine is moved.

FIG. 314.



The larger wheel, A, is eight inches in diameter, of thin wood, and, like all parts of the machine, is covered by several coats of oil-paint, so as entirely to exclude the water. The side shown is divided into compartments of variously colored circles, so that, when in motion, these colors are blended each into a single color, presenting a very striking chromatic experiment. Its elevation on the top of the iron tube is about six feet from the basin into which the water falls. The other side presents the solar spectrum, the seven colors being painted in their respective proportions to each other, so as to form white by revolution, when the wheel is in motion. Experiment, however, shows that it is not without difficulty that a perfect white is presented by such means. This subject is explained and illustrated at page 278.

DAGUERREOTYPE.

363. This branch of photography was the invention of M. Daguerre, an ingenious French artist, and is entirely independent of the art of taking impressions on paper, as above described. In that the pictures are reversed, in this they are in the natural position, and, instead of paper, the picture is on silver.

As an art, this is one of the most curious and wonderful discoveries of the present age; for, when we witness the variety of means necessary to the result, it would appear equally improbable that either accident or design could possibly have produced such an end by means so various and complicated, and to which no other art, (save in the use of the camera obscura,) has the least analogy in the manner in which the object is accomplished.

This being a subject of considerable public interest, and, withal, a strictly philosophical art, we shall here describe all the manipulations as they succeed each other in producing the result, a human likeness.

The whole process may conveniently be divided into eight distinct operations. 1st. Polishing the plate. 2d. Exposing it to the vapor of iodine. 3d. Exposing it to the vapor of bromine. 4th. Adjusting the plate in the camera obscura. 5th. Exposing it to the vapor of mercury. 6th. Removing the sensitive coating. 7th. Gilding the picture. 8th. Coloring the picture.

1. *Polishing the Plate.*—The plates are made of thin sheets of silver, plated on copper. It is said that, for some unknown reason, the photographic impression takes more readily on these plates than on entire silver. The silver is only thick enough to prevent reaching the copper in the process of scouring and polishing.

The polishing is considered one of the most difficult and important manipulations in the art; and, hence, hundreds of pages have been written to describe the various methods devised and employed by different artists and amateurs.

We can only state here that the plate is first scoured with emery, to take off the impressions of the hammer in plenishing; then pumice, finely powdered, is used, with alcohol, to remove all oily matter, and, after several other operations, it is finally given the last finish by means of a velvet cushion covered with rouge.

2. *Iodizing the Plate*—After the plate is polished, it is in-

stantly covered from the breath, the light, and the air, nor must it be touched, even on the edges, with the naked hand; but, being placed on a little frame, with the face down, it is carried to a box containing iodine, over which it is placed as a cover. Here it remains for a moment or two in a darkened room, being often examined by the artist, whose eye decides, by the yellowish color to which the silver changes, the instant when the metal has combined with the proper quantity of iodine. This is a very critical part of the process, and requires a good eye and much experience. The vapor of iodine forms a film of the iodide of silver on the metal, and it is this which makes it sensible to the light of the camera, by which the picture is formed. If the film of iodine is too thick, the picture will be too deep, and dark; if too thin, either a light impression, or none at all, will be made.

3. *Exposure of the Vapor of Bromine.*—Bromine is a peculiar substance, in the liquid form, of a deep red color, exceedingly volatile, very poisonous, and having an odor like chlorine and iodine, combined. It is extracted from sea-water, and the ashes of marine vegetables.

This the photographic artists call an *accelerating* substance, because it diminishes the time required to take the picture in the camera obscura.

The iodized plate will receive the picture without it, but the sitter has to remain without motion before the camera for several minutes, whereas, by using the bromine, the impression is given in a minute, or in a minute and a quarter. Now, as the least motion in the sitter spoils the likeness, it is obvious that bromine is of much importance to the art, especially to nervous people and children.

The bromine is contained in a glass vessel closely covered, and is applied by sliding the plate over it for a few seconds.

4. *Adjusting the Plate in the Camera.*—The plate is now ready for the photographic impression by means of the camera. If a likeness of a person is to be taken, he is already placed before the instrument, in a posture which the artist thinks will give the most striking picture, and is told that the only motion he can make, for a half a minute to a minute, is *winking.*

The artist now takes the plate from a dark box, and, under cover of a black cloth, fixes it in the focus of the lens. This is done in a light room, with the rays of the sun diffused by means of white curtains.

The artist having left the sitter for the specified time, returns, and removes the plate for the next operation. Still, not the least visible change has taken place on the bright surface of the silver. If examined ever so nicely, no sign of a human face is to be seen, and the sitter who sees the plate, and knows nothing of the art, wonders what next is to be done.

5. *Exposure to the Fumes of Mercury.*—The plate is next exposed to the fumes of mercury. This is contained in an iron box, in a darkened room, and is heated, by means of an alcohol lamp, to about 180 degrees, Fah. The cover of the box being removed, the plate is laid on, with the silver side down, in its stead.

After a few minutes, the artist examines it, and, by a faint light, now sees that the desired picture begins to appear. It is again returned for a few minutes longer, until the likeness is fully developed.

If too long exposed to the mercury, the surface of the silver turns to a dark ashy hue, and the picture is ruined; if removed too soon, the impression is too faint to be distinct to the eye.

6. *Removal of the Sensitive Coating.*—The next operation consists in the removal of the iodine, which not only gives the silver a yellowish tinge, but, if suffered to remain, would darken, and finally ruin the picture. Formerly this was done by a solution of common salt, but experiment has shown that the peculiar chemical compound called *hyposulphate of Soda*, answers the purpose far better. This is a beautiful transparent crystalized salt, prepared by chemists for the express purpose.

A solution of this is poured on the plate until the iodine is entirely removed, and now the picture, for the first time, may be exposed to the light of the sun without injury, but the plate has still to be washed in pure water, to remove all remains of the hyposulphate, and then heated and dried over an alcohol lamp.

7. *Gilding the Picture.*—This is called *fixing*, by the chloride of gold.

Having washed the picture thoroughly, it is then to be placed on the fixing-stand, which is to be adjusted, previously, to a perfect level, and as much solution of chloride of gold as the plate can retain, poured on. The alcohol lamp is then held under all parts of it successively. At first the image assumes a dark color, but in a few minutes grows light, and acquires an intense and beautiful appearance.

The lamp is now removed, and the plate is again well washed in pure water, and then dried by heat.

Before gilding, the impression may be removed by repolishing the plate, when it is perfectly restored; but, after gliding, no polishing or scouring will so obliterate the picture, as to make it answer for a second impression. Such plates are either sold for the silver they contain, or are re-plated by the electrotype process.

8. *Coloring the Picture.*—Coloring daguerreotype pictures is an American invention, and has been considered a secret, though at the present time it is done with more or less success by most artists.

The color consists of the oxyds of several metals, ground to an impalpable powder. They are laid on, in a dry state, with soft camel-hair pencils, after the process of gilding. The plate is then heated, by which they are fixed. This is a very delicate part of the art, and should not be undertaken by those who have not a good eye, and a light hand.

PHOTOGRAPHY.

364. The photographic art, which literally means "picture making by light," owes its present state of perfection to the untiring and long-continued zeal of several scientific men in France, England, and America. It is a curious and highly interesting fact, that all the materials by which the desired result is produced, with the exception of the salts of silver, are of recent discovery, as collodion, bromine, and iodine, and, without the use of which, the art in question must have remained unknown.

1. At the present time, the photographic picture is produced by first taking the likeness on a glass plate, prepared for this purpose, by covering it with a mixture of collodion and iodine (collodion is dissolved gun-cotton). This is done that, when the plate is dipped in a solution of nitrate of silver, a sensitive coat, the iodide of silver, may be formed on it. The glass plate, thus prepared, is next placed in the camera, in the usual manner for taking daguerreotype pictures, and the picture is formed by the same process.

2. A sheet of white paper is prepared for the image by coating it with a solution of nitrate of silver, and drying it in the dark.

3. This paper is next placed on the coated surface of the plate, and the whole is exposed to the direct rays of the sun, when the desired picture is the result of the action of the light on the prepared paper, through the image already contained for this purpose on the glass plate.

Several of the distinct processes by which the plate is prepared for use are common to the daguerreotype art, and need not, therefore, be repeated here.

First rate Photographic pictures are produced by Mr. N. A. Moore, No. 152 Main street, Hartford, who has been so kind as to furnish us with the elements of the above statement.

MORSE'S ELECTRO-MAGNETIC TELEGRAPH.

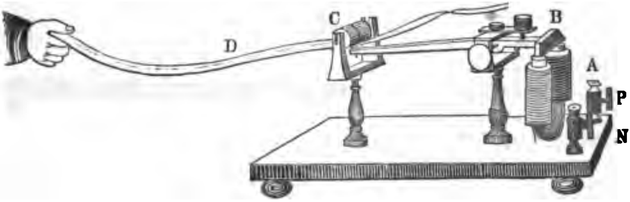
365. The means by which Mr. Morse has produced his wonder-working and important machine is the production of a temporary magnet, by the influence of the galvanic fluid.

We have already described the method of making temporary magnets of soft iron, by covering the latter with insulated copper wire, to each end of which the poles of a small galvanic battery is applied.

The description of *Fig.* 308, with what is said before on the subject, will inform the student how the power is obtained by which the philosopher in question has brought before the world such wonderful and unexpected effects.

The machine itself is sufficiently simple, and will be comprehended at once, by those who have made electro-magnetic experiments, by the annexed diagram and description.

FIG. 315.



Principle of Morse's Telegraph.

366. *Description.*—The U magnet, A, *Fig.* 315, is prepared, as already described, by being surrounded by many folds of insulated wire. The armature, B, is fixed on a lever, acting on a fulcrum, and passing to the roller, C. This end of the lever is armed with a point, by which the marks are made, answering to the letters of the alphabet. The strip of paper, D, comes from a roller, not seen, passing between the roller, C, and the point. The cups and thumb-screws, P N, are for the purpose of securing the two magnetic poles of the battery, when in use. The cups contain mercury as usual.

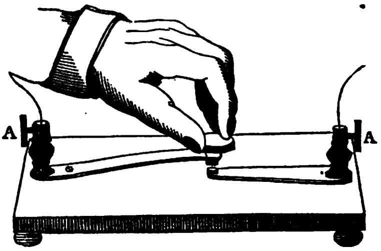
367. *Action.*—Having described the machinery, its action is as follows: It has already been explained that, when a bar of

soft iron, covered by insulated wire, has its two poles connected with a galvanic battery, the iron instantly becomes a magnet, but returns to its former state the instant the connection between them is broken. To break the circuit, it is only necessary to take one of the polar wires from the cup N or P. Suppose then that the poles of the U magnet are in the cups, and every thing ready for a telegraphic communication, then, one of the poles of the battery being already in the cup, the other being inserted, the armature, B, is attracted, and the point on the lever is elevated, making its mark on the strip of paper, D, which is drawn along under the roller, C, by a weight, not seen in the figure.

The lever, being a spring, the instant one of the poles of the battery is taken from the cup, the U magnet loses its force, and the armature rises, thus leaving a blank on the paper

368. *Signal Key.*—This part of the instrument consists of two strips of brass, each furnished with screw cups, *Fig.* 316. The end of one of these strips is over that of the other, and is furnished with a knob, which, being depressed, completes the communication or circuit of the telegraphic line; but, on removing the hand, the knob rises and the circuit is broken by the action of the lever. Thus, by depressing the knob, as shown by the figure, the signal is given, at the other end of the line, that all is ready for communication, and, by this means, the telegraphic alphabet is made.

FIG. 316.



Signal Key.

369. *Distance between the Magnet and Battery.*—Now, with respect to the distance apart at which the temporary magnet and writing apparatus and the battery are placed, experiment shows that it makes little difference, with respect to time. Thus, suppose the battery is in Hartford, and the magnet in New York, with copper or iron wires reaching from one to the other. Then, the telegraphic writer at Hartford, giving the signal, by means of an alarm-bell, that he is ready to communicate, draws the attention of the person at New York, to the apparatus there.

If now we suppose the letter A is signified by a single dot, he at Hartford depresses the key, and instantly, at New York, the soft iron becomes a magnet, and a dot is made on the paper, and so the rest of the alphabet.

The wires are carried through the air by being wound around glass caps supported by iron L shaped arms, which are driven into wooden posts, about 20 feet from the ground. These posts are erected for this purpose chiefly on the railway-lines, from 50 to 100 feet apart.

VELOCITY OF ELECTRICITY.

370. The long experience of the officers of the United States government on the coast survey, with telegraphic lines, have enabled them to measure the velocity of the galvanic current with uncommon accuracy. From experiments and calculations thus made, it appears that its velocity is about *fifteen thousand four hundred miles per second.*

The period of its transit between Boston and Bangor, was recently measured, and the result was, that the time occupied in its passage, was the *one hundred and sixtieth of a second.* According to this experiment the velocity is at the rate of 16,000 miles per second, which it appears is about 600 miles per second more than the estimates made on the coast survey.—*Annual Scientific Discoveries.*

Telegraphs in the Country.—According to a recent estimate, the length of telegraphic lines in the country, in actual operation, is not far from 20,000 miles.

The most remote points in communication are Quebec and New Orleans; their distances apart, following the circuitous routes of the wires, being about 3,000 miles.

Number of Stations.—The number of towns and villages accommodated with stations, and from which, therefore, intelligence by telegraph, from one to the other, or from one to all the others, can be interchanged, are between 450 and 500.

371. *Accidents on Rail Roads.*—Nearly all the rail roads in the country are furnished with telegraphic lines and stations, so that, in cases of accidents on the road, information of the disaster can be sent from one part of the country to another in a few minutes. On this subject, we record the following from a source supposed to be correct. During the year 1855, the number of accidents in the country, resulting chiefly from the carelessness of those employed on rail roads, have been 142; number of persons killed, 116; number wounded, most of them badly, 539. About 60 of the killed were employed on the roads; of which, 20 were engineers, and 6 conductors.

TELEGRAPHIC TALKING.

372. It is one of the wonders of this age of scientific developments, that, instead of writing down, by signs, the language of Morse's telegraph, the operator is now guided only by the click of the lever, the sounds of which are produced by the action of the armature against the temporary magnet. This ticking is the telegraphic alphabet, made by the actuary, who sends the message, but is not reduced to a written language, as formerly; not a scrap of paper, or a mark of any kind, being now employed; the ear only being the organ by which the attendant here is guided in writing down the message from abroad. To a common ear, this ticking of the lever would convey nothing more than the dropping of water on a rainy day, and yet, there is a scientific arrangement, a system, in the number of ticks, and the intervals between them, by which the attentive listener, after many months practice, is able to derive a language, by which communications on every subject connected with the wants, the wishes, and the passions of man, are distinctly and definitely made. In addition to communications from a distant city, which I saw written down from the ticking of the machine, I was informed by the intelligent young gentleman who has charge of the instrument, that, between those who had learned this art, there was no use for the tongue; but, that they could convey to each other any idea desired, by merely rapping on the table with the knuckle.

MORSE'S TELEGRAPHIC ALPHABET.

Alphabet.	Alphabet.	Alphabet.
A - —	N — -	& - - - -
B — - - -	O - -	———
C - - -	P - - - - -	Numerals.
D — - -	Q - - — -	1 - — — -
E -	R - - -	2 - - — - -
F - — -	S - - -	3 - - - —
G — — -	T —	4 - - - - —
H - - - -	U - - —	5 — — —
I - -	V - - - —	6 - - - - - -
J — - — -	W - — —	7 — — - -
K — - —	X - — - -	8 — - - - -
L ———	Y - - - -	9 — - - —
M — —	Z - - - -	0 ———

The following is a specimen of the language above described, by which it will be seen how dots and dashes can be rendered into language. We are told that, at least, a year is required to become an adept in this art.

H	a	v	e	y	o	u	s	e	n	t
····	·—	···—	·	·· ··	· ·	··—	···	·	—·	—

t	h	e	m	o	n	e	y
—	····	·	——	· ·	—·	·	·· ··

Remark.—It is only on the principal telegraphic routes that this method has been adopted.

HOUSE'S PRINTING TELEGRAPH.

373. This instrument, one of the wonders of our time, prints all communications in Roman capitals, and that much more rapidly than the most expert compositor.

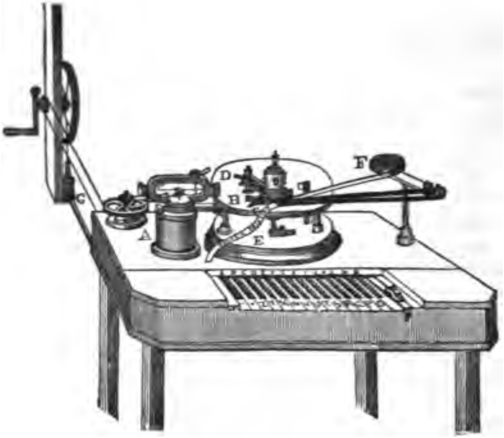
To go into a description of all its parts would probably so confuse the mind of the reader, that, in the end, none of it would be understood. We shall, therefore, describe only such portions of the machinery as are necessary to show how the result is produced.

In the first place, when a communication is to be made from one city to another, notice is given, by an electrical current on the wires, which occasions a vibration of a part of the machinery, and by which the attendant knows that a message is to be sent. At every station there is an electrical battery, consisting of 12 or 14 cups, the power most commonly used being that known as Grove's battery, a description of which may be seen in another place.

The forms of all visible parts of the instrument are shown by *Fig.* 317. That portion by which the printing is performed consists of a soft iron, or electro-magnet, contained in the cylinder, A, of an escapement, B, moved by condensed air, by means of the pump, G, above which is seen the band by which that part of the machinery is turned; D is the printing apparatus, the projecting portion being the lever; E is the inking band, by which the type are inked for printing; F is a strip of paper for printing.

This engine is moved by a boy, who turns the wheel by the lever shown, and by which air is condensed by the pump, G, and, by the force of which the printing portion of the machinery is actuated.

FIG. 317.



House's Printing Telegraph.

The action of the electricity in this telegraph is merely to produce a correspondence of motion in the machinery at the different ends of the line. All the mechanical results are produced by local, mechanical power, connected with the printing apparatus at each station, where manual force is employed for this purpose.

374. The letters on the keys, moving by the touch like those of the piano, are the instruments by which the different letters are, one by one, printed from one station to the next. Thus one letter of the 26, on the different keys, will be printed at the other end of the line, when that letter is depressed. This is done by converting a piece of soft iron into a magnet at the next station, on the principle already explained and illustrated, in the description of Morse's telegraph, only that the letter, instead of the point, is made to act or advance.

This is a most complicated machine, as a whole, though its different parts are sufficiently simple. The effect, though the means are so difficult to understand, is highly curious and interesting, as it prints Roman capitals at the rate of 150 or 200 in a minute. This is done on strips of paper an inch wide; and, when in operation, any one may print a sentence, as his own name, by touching the keys on which the letters are placed which spells the sentence.

PRINTING PRESS.

375. *Remarks.*—In our last revision, we inserted some account of the art of printing, with the forms of presses used for that purpose at various periods. But these presses are now so common that nearly every village can boast of one or more, so that any school boy can see the machine itself and in actual use. We have, therefore, thought that it would be a useless expense of time, to offer the student the picture of a thing of which he can see the original, and therefore have occupied the space, formerly reserved for this subject, with more interesting and important matter, viz: illustrations of the *Gas meter.*

SHARP'S RIFLE.

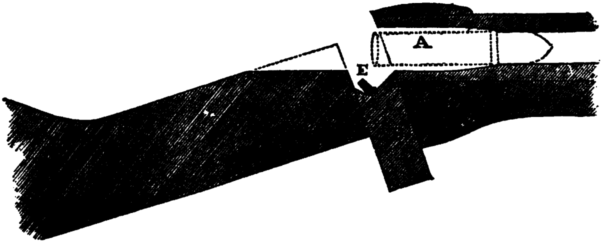
376. This is undoubtedly for the purpose designed, the most perfect and efficient single instrument of destruction ever invented; and of which, we here propose to give such a description, with illustrations, as to make all its peculiarities readily understood.

The *barrel* is about 22 inches long, and the bore of the size to admit round balls of 32 to the pound; but being elongated, or acorn-shaped, the number is only 18 to the pound.

This rifle loads at the breech, the form of the ball inclosed in its cartridge being shown at A, *Fig.* 318, introduced into its place.

The *slide*, B, which takes the place of the breech pin in other guns, is a solid piece of steel, represented depressed for the introduction of the ball. The *cone*, E, is that part on which the percussion cap, or its substitute, is exploded, and which inflames the charge in the gun.

FIG. 318.



Sharp's Rifle.

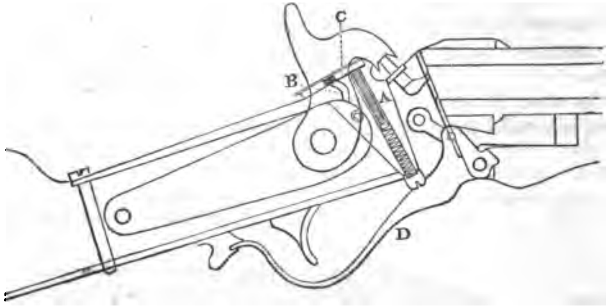
The manner in which the breech slide is depressed, will be understood by the section, *Fig.* 319, where D is the lever by which it is drawn down for the introduction of the ball, and then elevated preparatory to the discharge. The upper and anterior portion of the slide, has a cutting edge, seen above B, *Fig.* 318, which separates the end of the paper cartridge, thus exposing the powder to the action or the percussion priming, by which it is inflamed and the gun discharged.

377. *The Priming.*—The former mode of discharging this rifle was by means of Maynard's patent priming, which consisted of kernels of percussion powder, inclosed in varnished paper. But this mode the inventor of the rifle found objectionable on several accounts, and especially as it became useless on exposure to moisture.

He therefore invented a new, and an entirely original mode of priming, which has been recently patented, and which he has allowed the author to figure, and explain for the use of this work.

This consists of the tube, A, *Fig.* 318, of iron, about the one-fifth of an inch in diameter, and two inches long, called the *magazine.* In the lower part of this is a spring, above which are the priming discs, consisting of thin, round envelopes of copper, containing the percussion powder, completely protected from moisture, so that they may remain under water for hours, or weeks, without damage.

FIG. 319.



Sharp's Rifle.

Each tube holds 60 of these primers, one of which is forced up against the slide, C, by the spring. When the hammer is drawn to the back notch, the *slit*, B, working on the arm of the *slide*, C, which is fastened to the plate of the lock, draws it back from over the tube, A, and admits one of the percussion discs in front of the slide at C, and by which, when the trigger is pulled, it is thrown forward, between the face of the hammer and the cone, where it is instantly exploded, and the rifle discharged.

One of the most singular and curious results of this mechanism, is, that the percussion disc is struck, as it were, "on the wing," or while it is flying between the hammer and the cone; and yet it never fails to explode in the proper place and discharge the gun, let its position be vertical or horizontal.

378. *Practical effects of this Rifle.*—We have seen this arm fired at a target at the several distances of 300, 500, 600, and 700 yards, being respectively 900, 1,500, 1,800 and 2,100 feet.

The target was a pine board 30 inches square, and by the inventor was hit on the average, twice out of three shots.

By experiments and calculations lately made in France, it was found that a man, at the distance of 1,638 feet, appears to the naked eye only one-fifth his real size, and therefore, by this estimate, a target of 30 inches in diameter, at the distance of 2,100 feet, appears less than six inches square, a small object truly in practice, and requiring an accuracy of aim so minute, that the tenth of an inch in the direction of the sight, would carry the ball far aside of such a mark, and yet it was pierced twice out of three shots.

379. *Adjusted Sight.*—This rifle has an adjusting sight, which is elevated, or depressed and fixed, according to the distance of the mark. All the shots were made, with the gun in the hands, or without a rest, and also, with the striking peculiarity of being placed on the left shoulder.

Fatal at the Distance of a Mile.—Although in the above trial, the distance was only 700 yards, the inventor has proved by experiment, that this rifle throws its ball with a force equal to the destruction of human life to the distance of a mile.

In battle, therefore, the approaching enemy can be effectually assailed with this arm, at that distance, the aim, of course, being more and more sure, as the distance diminishes.

Number of Balls Thrown.—The rapidity with which this arm may be loaded and fired is such, that if one ball be sent along the surface of water, another may be made to follow before the first ceases its motion.

The inventor loads and fires it ten times in a minute; but estimating that in battle the number of balls fired by each soldies would be only six in a minute, then 1,000 men would discharge 6,000 in a minute, or 360,000 in an hour.

380. *Invention of Gunpowder.*—In Europe, the invention of gunpowder is attributed to Roger Bacon, who died in 1292; but it seems to have been known to the Chinese long before that period.

The first account of its use in European war, was at the battle of Cressy, in 1346, and from that time it superseded, chiefly, all other means of destruction on the battle-field.

Effects of this Invention.—There is no doubt but this invention has proved a humane—a merciful discovery in the art of war.

Before its use, the instruments of death in battle, were the barbed arrow, the halbert and spear, various kinds of swords, and the war-club.

The combatants fought hand to hand, each one trying to inflict the most cruel tortures on the other; and, indeed, the instruments employed, were much better calculated for this purpose, than for the infliction of sudden and quiet death.

On the contrary, gun-shot wounds, when not instantly fatal, afford a prospect of recovery, while those made by the barbed arrow and spear, more commonly portend a miserable death, after protracted agony.

Besides, if we examine the accounts of ancient battles, we shall find, that including the carnage on the field, and the number who died of their wounds afterward, the destruction of human life, where an equal number were engaged, was much greater than it was, after the invention and use of gunpowder.

381. *Conclusion.*—Although there is no doubt but the use of fire-arms, in warfare, has heretofore diminished the horrors of the battle-field, this circumstance, as history informs us, has had no influence on our species, except to foster an increasing desire to render the instruments of death more and more perfect, so that in the day of battle, the carnage should be as sudden and as great as possible. And hence, within a few years, great improvements have been made on fire-arms in France, England, Germany, and America, all tending, of course, to the increase of their destructive effects.

The inventors of these improvements in the arts of human destruction, are by no means considered by political, or even by moral and religious writers, as enemies of the human race, but are viewed, at least, by many such, as the pioneers of universal peace, if, indeed, fallen man should ever cease to learn and practice the art of war.

382. *Settlement by Arbitration Improbable.*—The history of man affords no foundation for the belief that national quarrels will be settled by the intervention, or arbitration of other nations, and hence, there can be little doubt, if the moral and political condition of the world remain as heretofore, that "nation will continue to lift up its arm against nation," and that the day when "man shall learn war no more," is *not* at hand, unless indeed, it should be by the approach of the millenium.

Under this view of the case, the only prospect of universal and permanent peace, is in such a degree of perfection in the art of war, that certain death awaits at least five out of six of all who enter as combatants on the field of battle; and in naval warfare, an equal proportion of ships shall as certainly be buried in the ocean.

Until such a state of things exist, men will continue to engage each other in mortal strife; and it is on this account that moralists of the present day, look with favor on the improvements in fire-arms, knowing that the paramount design of all such inventions is to render escape more difficult, and death more sudden and certain on the battle ground.

Nor is it probable that the time is far distant, when at least ten will fall on the field, where with an equal number of combatants, only one fell 30 years ago; the result being solely from the more deadly power of the fire-arms employed.

The author having served as surgeon on the frontier, in the U. S. Army, in the war of 1812–15, is able to appreciate, in a measure, the difference between the destructive power of the fire-arms then furnished by the government, and those now to be introduced into the army of the United States.

383. *Contrast between Old and New Arms.*—To those who have examined this subject, and are acquainted with the arms employed formerly, and those now going into general use, it will not be considered an over estimate to suppose, that 100 men armed with Sharp's rifles, and Colt's revolvers, would commit greater carnage, on the battle ground, than 1,000 men could do, with the flint lock, government muskets, in former use.

384. Who, indeed, will enlist into a military service when he knows that his enemy will oppose him with messengers of death, at the rate of 600 per minute, or 36,000 per hour, for every 100 men, and this at the distance of a mile, or less; and with the same number of such messengers, in half that time, when within any distance between 20 yards, and the reach of the

bayonet; which will be the case when armies are supplied with Sharp's rifles, and Colt's revolvers.

From such sources only, according to the present aspect of the nations of the earth, can we look for permanent peace.

COLT'S REPEATING PISTOL.

385. This celebrated fire-arm has been brought to its present degree of perfection, only after years of experience, trial, and invention, by the original patentee, Col. Samuel Colt, of Hartford, Conn.

An account of this weapon is introduced here, as an invention with which all the civilized nations of the earth, are now, or are soon, to become acquainted.

As Americans, therefore, we are bound to know something, at least, of the history and mechanism of so important an invention.

The examination and trial of Colt's revolvers at the World's Fair, and the award passed upon them there by the best judges, and the most experienced military men of the age, are ample and sufficient proofs that this, for the purpose for which it is designed, is the most efficient and perfect fire-arm ever invented.

The immense demand for the article in foreign countries, as well as in our own country, evinces, also, that no substitute exists for this weapon.

About 400 artificers, we understand, are employed in their manufacture, which number, it is stated, is to be increased to 1,000, in order to supply the demand.

The United States government have adopted Colt's repeating pistol, as the best weapon known, for mounted men, both for offensive and defensive use. And in the Mexican war, no officer who could obtain a revolver, ever went a day without one, and those who could not, often considered their lives in peril, in consequence.

386. In 1851, the President of the United States in a message to the Senate, states, that

"Such is the favorable opinion entertained of the value of this arm, particularly for mounted corps, that the secretary of war has contracted with Mr. Colt, for four thousand of his pistols," without waiting a special appropriation of Congress. This contract, of course, was confirmed by the Senate.

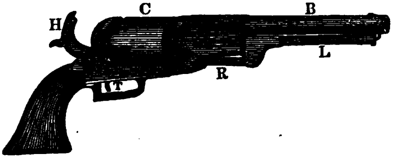
Such is considered the importance of this arm as a weapon of defence, that the military committee of the House of Representatives, recommend that it should be furnished to emigrants, as the following shows.

"We, the undersigned, members of the military committee of the House of Representatives, understanding that an application is pending before your committee, favorably commended by the ordanance department, for the purchase of a suitable number of Colt's, pistols and authorizing the department to furnish the same to emigrants at government prices, and to deliver the same to the States, under the act of 1808, for arming the militia, recommend the same to your favorable consideration, and believe that such a clause in the army bill would be desirable and proper."

Signed by the committee, nine in number, January, 1851.

387. *Description of Colt's Pistol.*—Why these arms are called *revolvers*, and by what means they are made the most efficient of fire-arms, for certain purposes, will be understood by *Fig.* 320, and the following explanation.

FIG. 320.



Colt's Pistol.

The letters by which the principal parts of the pistol are denoted, are the following, as seen on the cut. The *barrel*, B, is from three, to eight inches in length according to the size and design of the pistol. The *cylinder*, C, is the part which revolves, and from which the arm takes its distinctive name. The mechanism by which the rotary motion is performed, can not be shown by a single figure. The cylinder is pierced with six apertures, called *chambers*, each of which, when ready for action, contains a charge of powder and a ball. Caps are then put on the tubes, corresponding to each charge, and now the arm is ready for the discharge of six balls, as rapidly as the hammer can be drawn to the back notch and the trigger pulled.

The *hammer*, H, being drawn back to where it now stands, is made to strike, with its face, the cap on the tube, by which it is exploded, and the pistol discharged. Then on drawing the hammer back for another discharge, the mechanism makes the cylinder revolve *one notch*, by which the next cap is brought under the hammer, and by pulling the trigger, is discharged, and so of all the other charges. The *trigger* requires no explanation, being in all fire-arms the same. The *ramrod*, R, is connected with the *lever*, L, by the united action of which, the ball is pushed down the chamber to the powder.

388. Having explained the references, we will give the inventor's own directions for loading, &c.

"Draw back the hammer to the half notch, which allows the cylinders to be rotated; a charge of powder is then placed in each chamber, and the balls, without wadding, or patch, are put, one at a time, upon the mouths of the chambers, turned under the rammer, and forced down with the lever below the mouth of the chamber. This is repeated until all the chambers are loaded. Percussion caps are then placed on the tubes, when, by drawing back the hammer to the full catch, the arm is in condition for a discharge by pulling the trigger; a repetition of the same motion produces like results."

When this arm is prepared, therefore, all that is required in defence, or in action, is to draw back the hammer, and pull the trigger, until the six balls are discharged, which is done in less than half a minute.

GAS METER, OR MEASURER.

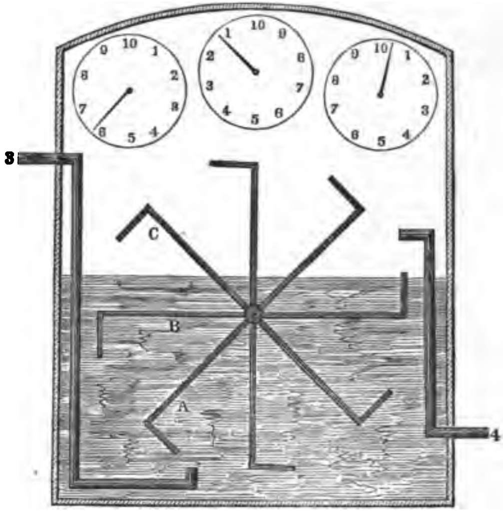
It is known to those who burn gas that a little tin box, having three faces like those of a clock, is placed in the cellar, and that by this, the agent ascertains how much gas has been used, and brings in his bill accordingly. Sometimes these meters are examined once a month, and then again only once a quarter, and yet the agent decides at once how many cubic feet of gas has been used since his last visit.

By what sort of mechanism contained in the little box, such results can be produced, has always been, and continues to be a mystery in the minds of those who have not examined the subject. Nor will any explanation by diagrams, or even the inspection of the meter itself, make the matter satisfactory without more time and patience than most people are willing to bestow on the subject.

We have, therefore, devised the plan represented by *Fig.* 321, as the most simple means of showing on what principle the meter acts. The meter itself is a more complex machine, but any one, by a mere inspection of the diagram, may see in a moment, that no difficulty exists in measuring the quantity of gas which passes through the water.

Suppose, then, that 1 and 2, *Fig.* 321, represents a tin vessel, 8 by 12 inches, filled with water up to C, and that in this is suspended, by an iron wire passing through the opposite sides of

FIG. 321.



Gas Meter.

the box, a revolving wheel, consisting of compartments, or buckets of tin, A, B, C, of which the *Fig.* shows a transverse section. The buckets are closed at each end, but open through their lengths, their forms being that of inclined planes, increasing from the center, as shown by the figure. These compartments are supposed to hold the eighth of a cubic foot each, and to be eight in number, so that one revolution will indicate a foot of the gas, as it passes through.

The gas is admitted, under the pressure of the gasometer, by the tube, 3, and passing down, rises through the water into the compartment, A, which, by its levity it raises to C, where it escapes into the box above the water, and passing out by the tube, 4, goes to the burner.

Meantime, the revolution of the wheel brings the several compartments over the end of the tube, and being each filled with the gas, it is discharged, and passes to the burner in a continued stream.

And now suppose that to the axis of this wheel, clock-work is attached, which shows the number of its revolutions, each indicating a cubic foot of gas, then the mystery of the gas meter is explained, at least, so far as its principle of action is concerned.

But, in the real meter, the three faces with their hands, placed on the upper portion of the box, indicate, in connection, the quantity of gas which has passed through the machine.

The indices of these faces are connected with each other, and with the prime mover, by means of very delicate clock-work, and by which, we will suppose, that No. 1, by the constant action of the wheel above described, is made to revolve once in 24 hours, during which time the hand of No. 2 passes from 0 to 1. Thus, 2 would revolve once in 8 days, while No. 3, during that time, indicates only a movement from 0 to 1, thus performing one revolution in 8 weeks; and thus it is obvious, that by a simple inspection of No. 3, once in 8 weeks, the quantity of gas consumed would be known.

Manufacture of Coal Gas.—Nearly every city in our country of any considerable size, is now lighted with gas, the chemical name of which is *carburetted hydrogen.* Formerly this gas was made by the distillation of whale oil, in iron retorts. At present, it is, we believe, exclusively made by the heating of bituminous coal, in large iron retorts, or cylinders, set in fire places of brick.

These retort-cylinders are six, or eight feet long, placed side by side in the furnace, and after the coal is put in, and before the fire is applied they are made air-tight by means of a door, and cement at the outer end. At the inner end there is an opening for the escape of the gas, as it is developed by the heat of the retort, and from which it passes through iron pipes into a large tube called the *hydraulic main,* which is half filled with water, and through which the gas passes, and into which its impurities are deposited.

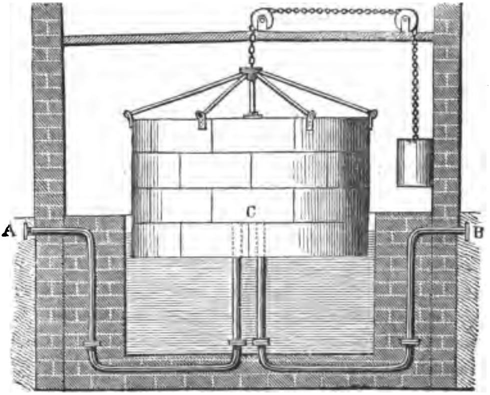
The gas then passes underground to the *lime-purifier,* where it is further purified by passing through a mixture of lime and water.

(As these processes have no peculiar interest for the student, we have omitted the illustrations.)

The gas is now fit for burning, and the next operation consists in conducting it to the *gasometer,* by the pressure of which it is sent to every part of the city, where it is wanted.

The gasometer, *Fig.* 322, is of a size in proportion to the number of burners expected to be furnished with the gas, some being only 20 or 30, while others are 60 or 80 feet in diameter. They are made of sheet iron, painted, open at the bottom, and set in a tank of water, ten or fifteen feet deep in the ground. This tank, made of brick, is cemented, so as to be water-tight on the inside.

FIG. 322.



Gasometer.

Into, or under this great vessel, the gas is admitted by a tube from the purifier, A, *Fig.* 322, where, rising up through the water, it lifts up, with the assistance of the weight seen in the cut, the gasometer, until its lower edge is near the surface of the water.

When the gas is wanted, a stop-cock is turned, and the pressure of the gasometer sends the gas through the tube, C, and so out at B, and thence to all places where it is burned.

The tubes of cast iron, through which the gas is sent, are from a foot, or more in diameter, gradually diminishing to two or three inches, and are laid two or three feet underground, through the streets. From these the gas is conveyed in small tubes to the houses, where it is burned.

SUBMARINE TELEGRAPH BETWEEN ENGLAND AND FRANCE.

This great project was carried into effect in 1851. The distance across the Straits of Dover, to the French coast, where the wire is laid, is 21 miles. It was constructed and laid down in the following manner:—

1. Three copper wires, No. 16, wire guage, were each separately covered with *gutta percha* of a quarter of an inch in thickness. These wires were then twisted together in form of

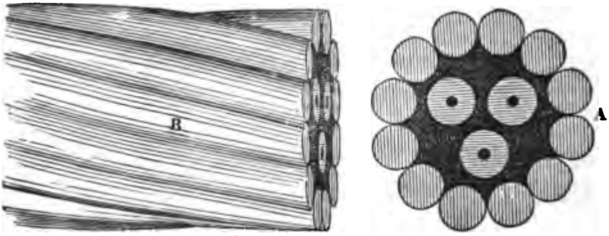
an ordinary rope. This copper and gutta percha rope was next covered with hemper yarn, previously saturated with a hot composition of pitch and tallow, the whole being carefully twisted, and compressed, and made to envelop the gutta percha with the force of steam machinery. Over this is another series of saturated hemper yarn, an inch in thickness, five or six coils, firmly encircling each other. Thus the gutta percha protects the wires, while this is protected by half a dozen coils of hemp rope. This completes the first coating.

2. Over, and embracing this, is a complete spiral covering, consisting of twelve galvanized iron wires, about the size of a lead pencil. This metallic sheathing is to protect the interior from the action of the rocks and sand at the bottom of the sea, and to increase the weight so that it will remain fixed in its place under the water, during storms.

The appearance of the cable thus covered with a coat of galvanized iron, is quite lustrous, silvery, and beautiful.

Telegraph from Europe to the United States.—The great project of laying the telegraphic wires from Cape Ray to Cape North, thus forming a union between Europe and America, by which messages may be sent from one, to another quarter of the globe, in 4 minutes, instead of two or three months, as was anciently the case, has thus far signally failed in consequence of a storm, by which the telegraphic cable was necessarily separated, leaving 40 miles of it at the bottom of the ocean. The whole length of this cable, made as above described, was 74 miles. It was manufactured by the Gutta Percha Company, city road, London.

FIG. 323.



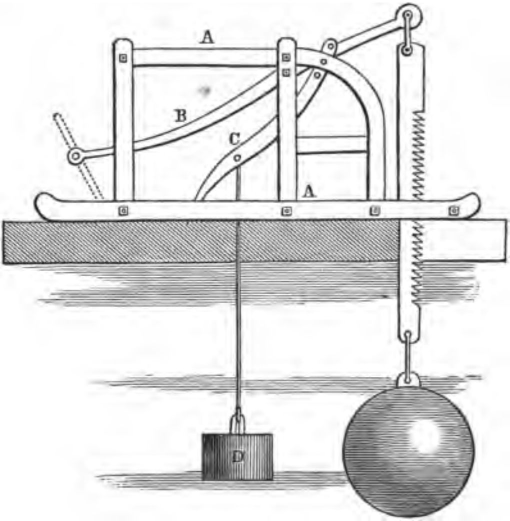
Fragment of Cable.

Having a piece of this cable in our possession, we have had the cross section A, *Fig.* 323, and the external covering of galvanized iron, B, each of the true size, engraved from it.

ICE SAW.

Machines for sawing ice, are of great importance in the Northern Seas, since the lives of the crew sometimes depend on the expedition with which the ship can be relieved from the icy barrier by which she is surrounded. On this account the ships employed in the Greenland fisheries are always furnished with saws fitted up with machinery for this purpose.

FIG. 324.



Ice Saw.

One of the best of these machines is represented by *Fig.* 324, which gives a side elevation of one half of the carriage by which it is moved. A A, is the frame resting on the ice; B, the lever by which the saw is worked, and the machine moved forward. C, the propeller, an iron bar of the shape seen, with the lower end divided into claws, to catch hold of the ice, and which it is made to do by the weight, D. The saw also has a heavy weight of iron, in order to draw it down and lift the lever. The machine consists of two such frames, as represented, firmly attached at the distance of two feet apart, and between them the saw lever and propeller.

Action.—The two weights, of course, are placed below the ice, then, on lifting the lever B, the saw goes down, and the propeller takes a step forward, by means of which, on depressing the lever, the machine is carried forward, again placing the saw in contact with the ice. This appears to be a very simple and complete machine for sawing ice, whether at home, or in the Northern seas.

ADDENDA.

Sometime after the discovery of the planet Neptune, Mr. Lassel, of Liverpool detected an attending Satellite belonging to that planet, about the size of a star of the fourteenth magnitude, and Mr. Bond, of Cambridge, thinks that he has discovered a second satellite, more dim and distant than the first. (See Neptune.)

With respect to the exact number of the heavenly orbs, we are not quite certain, it being reported that several have been recently discovered, but of which we have no certain information. For these, if any, the student must wait the next revision.

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